THE WEATHER

THE STORY OF
THE WEATHER

SIMPLY TOLD FOR
GENERAL READERS

BY

GEORGE F. CHAMBERS, F.R.A.S.
Of the Inner Temple, Barrister-at-Law

AUTHOR OF
"THE STORY OF ECLIPSES," "THE STORY OF THE STARS"
"A HANDBOOK OF DESCRIPTIVE ASTRONOMY," ETC.

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PREFACE

Let any of my readers try the following experiment:—ask the first person of their acquaintance who they may casually meet in the street such a question as, "Are you interested in Meteorology, and would you like me to lend you a book on the subject?" I feel sure that in four cases out of five, the answer would be, "No, thank you, I know nothing about it, and do not wish to know anything." But supposing the matter were broached in another form:—"Here is a little book which tells you a number of facts about the Weather, including some hints on how to become a weather prophet;" and the answer would be framed in quite a different spirit, *e.g.* "Yes; that ought to be interesting; I should like to have a look at it."

The foregoing imaginary dialogue will serve as a clue to the aims and scope of this little work. It does not in the least pretend to being a formal treatise on Meteorology, regarded as an exact Science,* but is merely designed to

* Mr. R. Inwards has very truly remarked in his interesting *Weather Lore*:—"Meteorology itself, especially as regards English Weather, is very far from having reached the phase of an exact science."

present in a handy form and in an unconventional style of language a certain number of elementary facts, ideas, and suggestions which ordinary people, laying no claim to scientific attainments generally, are usually glad to know.

The weather is a matter which comes very closely home to all the inhabitants of the United Kingdom. Notwithstanding the spread of Nineteenth Century luxuries in the shape of waterproof garments, goloshes, and things of that sort, the question of the weather of to-morrow, or of the day after, has often a very important bearing on the business and pleasures and health and convenience of all classes of the community of both sexes and every age.

The *raison d'être* of this little volume is therefore purely practical, and the reader must not expect too much from it.

I have to thank Mr. Steward, Mr. Casella, and Messrs. Negretti and Zambra for certain of the illustrations associated with their well-known names.

As regards the Weather predictions which will be found towards the end of this little volume, I shall be very glad to receive comments and suggestions for their correction and improvement.

G. F. C.

Northfield Grange,
East Bourne.

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CHAPTER I.

INTRODUCTORY STATEMENT.

An eminent writer, the author of the best book on the subject extant,* has defined meteorology as "the Science of the weather. The term was originally applied to the consideration of all appearances in the sky, astronomical as well as atmospherical; but it is now restricted to that department of natural philosophy which treats of the multifarious phenomena of the atmosphere that relate to weather and climate, their relations to each other, and the laws to which they are subject."

This brief but thoughtful sentence indicates only too clearly how large a field a writer might cover, and yet be within the reach of meteorology. A slight amount of reflection will make this quite clear. Let us suppose that he began by talking about the atmosphere simply. This at once would involve the composition of the atmosphere—the domain of chemistry. Then

* A. Buchan, *Handybook on Meteorology.*

the atmosphere might be considered as occasionally, one might almost say always, in motion. So looking at it, we should have to consider various branches of what is called natural philosophy; Dynamics for one. The transmission of sound through the atmosphere would bring us into Acoustics. The moisture of the atmosphere and its deposition as water brings in Hydrostatics. Hydrostatics, treated from another standpoint, takes us at once to streams, rivers, seas, oceans: here we are involved in Physical Geography. Quitting the surface of the Earth again, and having to consider, for instance, a thunderstorm, we are face to face with the Science of Electricity. Another common feature of a thunderstorm is a rainbow. In order to learn what a rainbow is, and how it is formed, we must dive into the Science of Optics. The most elementary acquaintance with Geography involves some knowledge of the existence of the "Trade winds." What is the cause of the Trade winds? They depend upon the rotation of the Earth. Why does the Earth rotate? What are the facts and laws connected with its rotation? For information on this subject we must go to the Astronomer: in other words, we must get up at least a little of the Science of Astronomy. The effect of a shower of rain, and the state of damp or dryness of a given country, or county, or parish from time to time, is materially affected by the nature of the soil on which the rain falls—whether the soil is porous, and the rains soon run through it; or whether it is heavy, such as clay, and the

rain lies long on the surface. To learn anything about soils we must go to the sciences of Geology and Mineralogy.

I have been thus particular in submitting to the reader the details exhibited in the preceding paragraph in order that he may realise how vast is the scope of the science of Meteorology in its broadest aspect, and how impossible it is to do justice to it in a volume of the size of the present one. This must be my excuse, if apology is needed, for limiting the scope of this book as narrowly as possible to everyday questions connected with the weather only, and only in their practical and popular aspect as affecting the business and pleasures of daily life. It is evidently under the circumstances of the case impossible to be very comprehensive, much less exhaustive.

Meteorology, in however limited a sense one may use the term, being evidently a science which comes home to everybody, or at any rate with which everybody comes in constant contact, is naturally a science which has received a large amount of attention from the earliest period. Numerous are the allusions to the weather, the rain, the clouds, the winds, which one meets with in the Bible, and several of these which embody recognised scientific truths will be found under their appropriate heads in a later part of this volume. The first to whom may be ascribed the credit of having worked up the weather in a methodical and definite manner was Aristotle, whose treatise on Meteors embodied a large amount of information, naturally, however, of very mixed value. It is probable that many

of his popular prognostics were derived from Egyptian sources, though no doubt many of them were also original. One of his pupils, by name Theophrastus, was also a labourer in this field, and left behind him a treatise on weather prognostics which includes a large amount of scientific fact which the moderns have had no sufficient reason to repudiate. Cicero and Virgil have also left on record various weather facts which make it clear that they devoted a certain amount of thought to the question. It is, however, true of Meteorology as of Astronomy, that the Romans did next to nothing in the matter compared with the Greeks; and that between the Greeks and the sixteenth century there stands a great gulf of time during which the whole subject of weather science seems to have gone to sleep; at any rate so far as we can judge by available literary evidence. The seventeenth century saw, however, various efforts which, both separately and together, gave a considerable impulse to weather study. It is evident that until instruments of precision were available records purporting to note hot summers and cold summers, dry summers and wet summers, &c., &c., could only be of a very rude and inadequate character. Once, however, that men of science became possessed of an instrument to indicate changes in the condition of the air (namely, the barometer), and changes in the condition of temperature (namely, the thermometer), it soon followed that the weather was made a matter of systematic study. With a very slender basis of fact to go upon, weather prophets started into

existence, and the almanacks of the eighteenth century which catered for that remarkable body the general public will often be found well supplied with rules of the most ridiculous character for foretelling the weather weeks or months in advance. As intellectual progress took place, so this sort of literature very properly fell into disrepute; at the same time it must be confessed that men of science contented themselves too long with merely recording numerical results indicated by such instruments as the barometer and thermometer; and were too slow in attempting to utilise the dry masses of figures which were accumulating year after year on an enormous scale, and lying absolutely idle in annual volumes, unread and unstudied.* One need only go to the Greenwich Observatory to find a forcible illustration of this in the immense number of figures of print which lie buried in the *Greenwich Observations* from 1750 to the present time, to utilise which hardly any attempt was made until that most industrious of modern meteorologists, Mr. James Glaisher, appeared on the scene at a comparatively recent period.

The largest amount of credit for utilising observations and trying to interpret them, and to republish their results for the good of the world must be given to the Naval Service, and

* Some of our financial reformers who occupy seats in Parliament would do a world of good to their country if they were to stop the wicked waste of money which goes on in connection with the printing of thousands of pages of expensive and utterly useless tabular matter which emanate annually from many of our public observatories.

in this connection the first names to come to mind are those of Sir W. Reid and Admiral Fitz-Roy as representative Englishmen, and Captain Maury as a representative American. These men, all amateurs, I mean not professed or professional men of science, were in their respective circles the first to focus and distribute *pro bono publico* weather knowledge which those who had gone before them had only gathered in order to bury.

CHAPTER II.

WEATHER FORECASTS AND STORM WARNINGS.

In August 1853 there was held at Brussels an International Maritime Congress at which meteorology as bearing on navigation was discussed. In 1854 a Meteorological Department of the Board of Trade was constituted under Admiral, then Captain, Robert Fitz-Roy, R.N., for the special purpose of rendering assistance to the Mercantile Marine in regard to meteorological matters. In 1859 the British Association recommended to the Board of Trade the circulation of storm warnings by the aid of the electric telegraph, such warnings to be reproduced in certain localities by the aid of a special code of signals to be devised for the purpose. As the result of this recommendation Admiral Fitz-Roy was directed by the Board of Trade to prepare a scheme for conveying to certain sea-ports connected by wire with London suggestive intelli-

gence of approaching storms. Nothing in the way of prediction, strictly so-called, was contemplated, only matter of fact announcements of storms actually in progress at some places, which storms might be expected after short intervals of time to manifest themselves at other places. This scheme, modest indeed as it was, marked, however, an entirely new departure in English Meteorological Science. Nothing at all approaching it had ever been essayed before, but the conductor of the movement was far from satisfied to be thus restricted; he thought even then that more could be done and ought to be done and that he would endeavour to do it; in short, that predictions or approximations to predictions two or three days in advance were often fairly possible and ought to be attempted. "From the very first the project was more or less opposed by many, and the old sea-wolves of the North for some time looked upon it with contempt. One day, however, Admiral Fitz-Roy ordered up his 'south cone,' meaning that a storm was approaching from the South. The good folks of Newcastle laughed at the signal. Why shouldn't they? The sky was clear and 'all serene.' *They* could see nothing to warrant the probability of a coming tempest. The fishermen put out to sea as usual. On the following morning, however, the coast was covered with wrecks, and many a family had to bewail the imprudence of the unfortunate men who had disregarded the signal. After that, people began to think that there was something in the system, and numerous subsequent fulfilments more and

more confirmed the popular belief in the utility of the predictions." *

The first cautionary or storm-warning signal was issued early in 1861, being the one alluded to in the foregoing extract. In August of the same year the publication of forecasts was commenced, and after six months had elapsed for gaining experience by varied tentative arrangements, the system was launched in its final form, which, so far as Admiral Fitzroy was concerned, remained in operation until his death in 1865. The ultimate procedure was the reception by telegraph of about 18 weather reports every morning (except Sundays) from British coast stations, besides a few from the continent. These reports gave (in cypher for the sake of brevity) the leading meteorological elements at the place of observation; such as the height of the barometer, the temperature, the wind, the rainfall in the previous 24 hours, the state of the atmosphere, and of the sea. The information thus conveyed to the office in London was immediately reduced by the application of necessary corrections, and written out on prepared forms. The first copy, with the original telegrams, was passed to the chief of the department, or his appointed deputy, to be studied and discussed for the forecasts intended to be issued on that day. About 11 A.M. expanded copies of the telegrams, together with the forecasts arrived at by the officer in charge, were sent to certain newspapers for publication in their next following issues.

* A. Steinmetz, *Manual of Weathercasts.*

Copies of so much of the forecasts as related to the English Channel were also telegraphed to the Ministry of Marine at Paris. The whole of this work was got through by about noon. In the afternoon, from a few of the stations, supplementary telegrams were received which were employed when necessary for the revision of the forecasts of the morning for insertion in the London morning papers of the following day. In addition to this daily service occasional storm-warnings were sent to our own coasts and to Paris, and sometimes to Hamburg and some other places in Germany by the request of, and at the expense of, various public authorities in the States concerned.

The signal apparatus employed under Admiral Fitz-Roy's directions comprised a mast of any convenient height (say 30 or 40 feet), two yards from 4 to 6 feet in length, with the necessary ship's tackle, a cone, a drum, and four signal lanterns. The cone and drum were wooden frames of those shapes, covered with strong canvass, and each about 3 feet high. Any suitable lanterns might be used so long as they were of good size, and showed the same colour. Red was preferred as the colour which is most conspicuous, and most generally associated with the idea of danger, or something intended to attract special notice.

When hoisted the cone would appear as a dark triangle, and the drum as a dark square, and the intended import of the various signals was as follows:—

The cone with the point upwards showed that

a gale was probable, at first from the Northward, this was termed for brevity, "North Cone" (fig. 1).

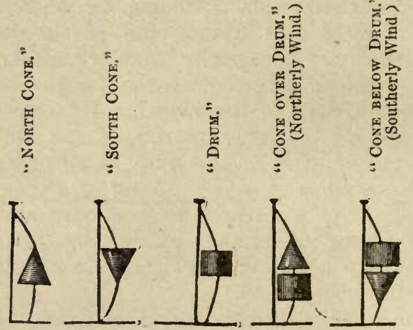

Fig. 1. Fig. 2. Fig. 3. Fig. 4. Fig. 5.

The cone with the point downwards showed that a gale was probable, at first from the Southward, "South Cone" (fig. 2).

The drum alone showed that stormy winds might be expected from more than one quarter (fig. 3).

The Cone and Drum hoisted together gave warning of dangerous winds, the probable first direction being indicated by the position of the Cone and the direction of its apex: Cone over Drum and point of Cone uppermost for Northerly wind (Fig. 4): Cone below Drum and point downwards for Southerly wind (Fig. 5).*

When the signals were hoisted at the several stations warned as the result of telegrams from

* The use of the drum has been discontinued.

London, they were to be kept up till the dusk of that day only, and in the official instructions it was stated that "these cautionary signals advert to winds during some part of the next night and two or three days; therefore due vigilance should prevail (until the weather is again settled) without deferring departures or any operations unnecessarily." At night only

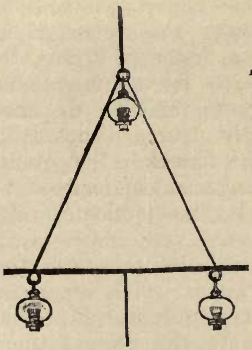

FIG. 6.
NIGHT SIGNAL EQUIVALENT TO "NORTH CONE."

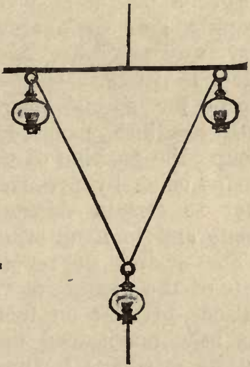

FIG 7.
NIGHT SIGNAL EQUIVALENT TO "SOUTH CONE."

one of the two signals was ordered to be used; Drum *or* Cone but not both. This was for the sake of simplicity and saving of trouble.

When the Fitz-Roy system was first instituted, the British Isles were divided into six Districts, namely —(1) Scotland, (2) Ireland, (3) West Central England, (4) South-west England, (5) South-east England, (6) East Coast of England. These six Districts were subsequently consoli-

dated into four, namely:—(1) Northern (Scotland), (2) Western (Ireland, Wales), (3) Southern (English Channel, Bay of Biscay). (4) Eastern (East Coast of England and the North Sea).

The telegraph being the agency for the transmission of weather news, and telegraphic messages, especially those involving figures, being costly and peculiarly liable to error, it became a matter of prime importance both to simplify and to abbreviate the messages in every way possible. As a first step it was decided to discard words as far as might be, except for special purposes, and to dispense with headings, using only figures disposed in groups, the position of the figures in the several groups being by pre-arrangement understood to refer to certain particular meteorological elements and to none others.

The system of reporting by telegraph the state of the weather at various widely separated stations, first set on foot by Admiral Fitz-Roy, has been maintained up to the present time, but its auxiliary feature, the digesting of this telegraphic news and the evolving from it of some general conclusions as to the weather probably imminent, was summarily stopped by official authority on the Admiral's death, and so a triumph was given to the party who looked upon him as a meteorological quack and unceasingly sought to disparage both him and his work. On the other hand, practical men unconnected with any scientific or official "ring," who had watched with pleasure the progressively improving value of the forecasts,

and especially those whose interests were most connected with the Mercantile Marine, learnt with great regret the decision of the Liberal Government of 1866 to stop the whole affair, and they made great and unceasing efforts to procure the revival of the Forecast system. The Government, it is true, did not in one sense give it an unqualified quietus; for after first referring the matter in an inquiring spirit to the Royal Society, they appointed a committee of three scientific men to look into the whole administration of the Meteorological Department of the Board of Trade, and to report thereon before the directorship vacated by Admiral Fitz-Roy's death was filled up, and this committee was specially enjoined to consider the forecasts as to their basis and value. Their report was adverse on the ground that sufficient data on which to found reliable predictions had not been accumulated; but this their expression of opinion was strangely at variance with the body of evidence to the contrary laid before them and actually printed by them in their Blue-book.

They addressed through one of the permanent officials of the Board of Trade to persons occupying official positions at various seaports, Collectors of Customs, Secretaries to Marine Boards, and the like, the following questions:—"What is the opinion of seafaring men concerning the value of the late Admiral Fitz-Roy's signals? Can you help us by telling me what is thought of them by those most competent to judge?"

The answers were with one exception highly

favourable to the Fitz-Roy system. The following are some samples of them. "The utility of the signals is generally acknowledged, and for some time back the subject has obtained more attention among seafaring men. The signals for a considerable time have been very accurate." Thus wrote a competent person at Aberdeen. Dundee said :—"The correctness of the storm signals at this port is a matter of common remark; they are very generally appreciated." The Shipowners' Society of South Shields stated that "the exhibition of the storm signals is of much practical value by giving timely warning of approaching storms." The testimony from Deal was very emphatic :—"There is but one opinion concerning the value of the signals. They have been the means of saving life and property to an immense amount." The other favourable answers were all couched in much the same terms. And in regard to the *one* hostile opinion it is worth mentioning that the writer (who hailed from Plymouth) seemed carefully to guard himself. He took shelter under the very vague phrase, "*Those most likely to be informed* on the subject do not consider that the signals are in any degree of value to seafaring persons." It must be conceded that this expression of opinion would have been more satisfactory had some degree of particularity characterised it, had there been some statistics, some actual record of the facts (*if any*) on which it was grounded. Considering the unanimity prevailing amongst the representatives of the Mercantile Marine on the subject and the untiring efforts they had made

to get the system again set on its legs, one is not a little puzzled to understand by what process of reasoning the committee arrived at the following astonishing conclusion:—"There is as yet no scientific basis for these daily forecasts, they are not shown to be correct in point of fact, and there is no evidence of their utility [! ! !], and we see no good reason why a Government department should continue to undertake the responsibility of issuing them," or, as they elsewhere in their report expressed it:—"There is no evidence to show that the daily forecasts have been correct in point of fact, or that we are enabled—as Admiral Fitz-Roy declared—to know what weather will prevail during the next two or three days, and as a corollary, when a storm will occur; on the contrary, the evidence points strongly the other way."

The ultimate outcome of the controversy was that the Meteorological Department of the Board of Trade was reconstituted on a new footing under the superintendence of a committee of eight Fellows of the Royal Society. In the first instance this permanent committee declined to undertake office except on condition that they were to have nothing to do with storm warnings, but facts were too strong for them, and in a very short time (May 1867) under public pressure from various influential quarters too strong to be resisted, the committee were compelled to "eat dirt" and allow the storm warnings to be resumed. Mr. R. H. Scott was the new director, but with powers less ample and unfettered than those wielded by Admiral Fitz-Roy. In point of

fact Mr. Scott's position at the outset was very much that of every public servant whose masters do not profess to believe in his work, but who appoint him to fulfil certain functions in obedience to an overwhelming pressure of public opinion which they are unable to circumvent. Mr. Scott's original appointment has been amply justified by its results, and allowing for the inherent difficulties and complexities of the subject it may fairly be said that there are few sub-departments of Her Majesty's Government in London in which so comparatively small a sum of Parliamentary money yields so large an amount of useful result.

Making due allowance for the progress of science and the natural changes in things which may be expected to have occurred in nearly 30 years, it may be said broadly that the system now in force is in effect the original Fitz-Roy system expanded and developed to meet the circumstances and requirements of the present day. A change, however, has been made in the territorial distribution of the districts into which the British Isles are now divided. There are now eleven of such districts, but having regard to the frequency with which, as our daily papers show us, these districts are combined for forecasts into ten, or eight, or sometimes as few as three, it may be questioned whether Admiral Fitz-Roy's original sub-division of the British Isles into six was really improved upon when he himself reduced the number to four, or when Mr. Scott on the other hand raised it to eleven.

The eleven now adopted are numbered and named as follows:—(0) Scotland, N.; (1) Scotland, E.; (2) England, N.E.; (3) England, E.; (4) Midland Counties; (5) England, S., London and Channel; (6) Scotland, W.; (7) England, N.W., and N. Wales; (8) England, S.W., and South Wales; (9) Ireland, N.; (10) Ireland, S.

The present position of matters as regards the work of the Meteorological Department of the Board of Trade may be conveniently summed up in brief form, somewhat as in the next following paragraphs.

The stations in daily telegraphic communication with the central office were at the end of March 1895, some 30 in number.

The storm warnings are sent of course to a great many more places than the places from which meteorological information is received. The stations warned were at the end of March 1895, 180 in number, situated, 103 in England and Wales, 48 in Scotland, 23 in Ireland, 3 in the Isle of Man, and 3 in the Channel Islands, being of course in nearly all cases places on the coast which may be said to be seafaring centres.

At various epochs during the last thirty years calculations have been made, alike by friends and foes, as to the proportions both of weather forecasts and storm-warnings which proved trustworthy. I do not care to burden these pages with any details on this subject, but taking one year with another, and one part of the British Isles with another, it may fairly be said that 75 per cent. of the announcements made turn out to

be more or less correct, and no more than 6 to 12 per cent. are hopelessly wrong.

Distinguishing between weather forecasts and storm-warnings, the latter used to be less generally successful than the former, but, as has been often pointed out, it is better to warn a ship's captain erroneously of a storm which does not happen than not to give him a warning of a storm which does happen. However, coming down to the present time, it appears that in 1894 as many as 92 per cent. of the warnings were followed by gales or strong winds, as against a percentage of 87 in 1890, and 79 in 1885. The whole question from a practical point of view may be properly epitomised in some such way as this :—granted that British weather is painfully uncertain, and the laws which regulate it very ill-understood, there can be no doubt that the few men in London who during the comparatively short period of about thirty years have tried to organise into intelligible shape existing weather knowledge for promoting the safety, comfort, and general welfare of their fellow mortals, have done vastly more than the army of professional meteorologists, mostly mere instrument-readers, in the great public observatories of Western Europe have done in the course of a century or more.

CHAPTER III.

PRACTICAL WORK AT THE LONDON METEOROLOGICAL OFFICE.

THE present daily work of the Meteorological Office may be briefly stated as follows. The first thing to be done is to obtain in a handy and convenient form a graphic record of present facts; this involves the preparation of what is called a synoptic chart, that is to say, a chart or outline map of the British Isles, which when filled in will furnish an intelligible view of the current weather. This is arrived at by interpreting and transferring to a blank map the information which arrives in London every morning at 8 a.m., from about thirty stations in the United Kingdom, giving the height of the barometer and thermometer, with the direction and force of the wind, together with the actual state of the weather. The first thing done is to mark at each station the then height of the barometer there. Lines are then drawn through all those places which have the same barometric pressure. If no two stations are alike, proportional differences are estimated so as to show approximately a series of lines probably corresponding to differences in the barometer of 10ths of an inch (such as 29·1, 29·2, 29·3, and so on), over as wide a range as is necessary to represent the facts of the case. Lines thus drawn are called "isobaric lines," or, shortly, "isobars,"

from two Greek words * signifying equal weight, because they pass through places on the Earth's surface where the weight of the atmosphere, that is, the barometric pressure, is equal. The nature and arrangement of these isobars at any given time, and their changes from time to time, form the most important element in the forecasting of the weather, especially as regards the direction and force of the wind in its influence on the weather.

After the isobars are marked in, the direction of the wind is marked on the chart by arrows which are supposed to fly with the wind, which arrows vary in form, each form having a particular meaning of its own. An arrow with one barb denotes a "light" wind: with two barbs a "fresh or strong" wind.

The force of the wind is estimated according to the well-known "Beaufort scale," so called from Captain Beaufort, R.N., its originator. On this system all possible forces or velocities are estimated on an arbitrary scale of 0 to 12, or from "calm" to the force of a "hurricane." The intermediate numbers are supposed to represent the number of knots per hour which a sailing man-of-war of the old type could make, or the extent of canvas which the wind would permit her to carry. Though the originating idea of this scale is very much of a rule-of-thumb character, and (so far as knots per hour of a sailing ship are concerned), somewhat out of date, yet the Beaufort system may be considered to be well established, not only in the minds of seamen, but of meteorologists. The last column of the

* *ἴσος* equal, and *βάρος* weight.

following table exhibits the estimated equivalent velocity in miles per hour of the arbitrary numbers given in the first column.

THE BEAUFORT SCALE.

				Velocity of wind in miles per hour.
0 Calm	...	... ...	... ...	3
1 Light air	=	Steerage way ...	... ...	8
2 Light breeze	=	All sail set, smooth water	1-2 knots ...	13
3 Gentle breeze	=		3-4 knots ...	18
4 Moderate breeze	=		5-6 knots ...	23
5 Fresh breeze	=	Just carry	Royals, etc. ...	28
6 Strong breeze	=		Single-reefed topsails, top-gallant sails ...	34
7 Moderate gale	=		Double-reefed topsails, jib, etc.	40
8 Fresh gale	=		Triple-reefed topsails, etc.	48
9 Strong gale	=		Close reefed topsails and courses	65
10 Whole gale	=	Scarcely bear close-reefed main topsail and reefed foresail		65
11 Storm	=	Reduce to storm-stay-sails	...	75
12 Hurricane	=	No canvas possible	... ...	90

The next thing done in preparation for the daily forecast is to mark on the map the weather at each station. For this purpose a system of abbreviations, known as the "Beaufort notation," is employed, as follows:—

b blue sky.
c detached clouds.
d drizzling rain.
f fog.
g dark, gloomy.
h hail.
l lightning.
m misty (hazy).
o overcast.

p passing showers.
q squally.
r rain.
s snow.
t thunder.
u ugly, threatening.
v visibility, unusual transparency.
w dew.

Last of all, the thermometer readings are marked on the chart, and lines are drawn through those places which have equal tempera-

tures, as was done for the equal barometric pressures. These lines are called "Isotherms," that is, lines of equal heat. This information, though interesting in its way, is not of much useful value in forecasting. The chart is then complete as a record of facts, and is ready for reproduction by the usual processes of the printer, lithographic or typographic, as the case may be.

The work next to be taken in hand is far more difficult than what has gone before: it is to interpret the record of the day with a view of determining what it implies as regards the probabilities of the morrow. These have especial reference in the first instance to wind, and, in a measure dependent on wind, to rain. Regarded from a seaman's point of view, the matter of chief importance is the direction and amount of the wind; the landsman is less concerned with the wind; he desires to know more about the probabilities of rain; will it fall or will it not fall?—questions often of great interest and importance to the agriculturist and gardener, not to speak of the cricketer and lawn-tennis player.

CHAPTER IV.

WEATHER CHARTS.

We shall consider in a later chapter some of the many co-relations subsisting between the barometer and wind and weather; in the present chapter it is proposed to give in an abstract form a few general ideas on weather as worked out in

some of the publications of the Meteorological Office.*

As regards the general direction of the wind—in few cases is this exactly parallel to the isobars, but is inclined at an angle of about 30° or 40°, while the relation relatively to the adjoining areas of high and low pressure may be expressed in precise phrases.

The general rule (commonly known as "Buys Ballot's Law") is :—stand with your back to the wind, and the barometer will be lower on your left hand than on your right. Hence it follows that the wind may be expected to be Easterly when the pressure is higher in the N. than in the S.; Southerly when the pressure is higher in the E. than in the W.; Westerly when the pressure is higher in the S. than in the N.; Northerly when the pressure is higher in the W. than in the E.

The least consideration will make it clear that the wind at any given moment can only be properly studied by an observer who has got before him the facts of the moment as transmitted over wide areas of land or sea by telegraphic messages from distant stations.

Now we have to consider the most important matter of all, important, I mean, as regards the necessities and convenience of the public at large—namely, the velocity of the wind, and here we have to deal with a very notable discovery of modern meteorology. The velocity of the wind depends in great measure on the amount of the

* Especially the Hon. R. Abercrombie's *Principles of Forecasting.*

difference of barometrical readings over a given distance. The term "gradient," so frequently met with in the daily weather reports, was first suggested by Mr T. Stevenson, C.E., as a convenient word to apply to differences of atmospheric pressure compared with the standard level; just as the same word had long been employed by civil engineers in connection with differences of level in the laying out of lines of railway, &c. A railway engineer records the steepness of a slope by noting the proportion between its vertical height and its horizontal length. For instance, a common gradient on a railway is 1 in 264, which means that, starting from a given point, when you have reached a distance of 264 feet on a track assumed to be level, you will have risen 1 foot above the level from which you set out.*

In the application of the term to barometer observations, the gradients are expressed in decimal parts of an inch of mercury per 15 nautical miles (or about 17 statute miles). This proportion was chosen for facility of comparison with the French metric scales: $\frac{1}{100}$th inch is nearly equal to $\frac{1}{4}$ millimetre, so that the definition adopted in England, as stated above, is almost equivalent to saying that the gradients are given in millimetres per 60 nautical miles, or 1° of latitude. It will be understood from the foregoing explanations, that when the isobars are wide apart, the gradient may be described

* This is another way of expressing a systematic rise of 20 feet per mile, but the vulgar fraction form of expression is found more convenient in practice.

as "moderate" or "gentle"; on the other hand, when the isobars are close together, that the gradient is "steep" or "abrupt." In a general way we may define a gradient as "moderate" when it varies less than $\frac{1}{100}$th of an inch (0·01 inch) per 17 statute miles of intervening distance. When the gradient is above $\frac{1}{50}$th of an inch (0·02 inch) for the like distance on the Earth's surface, it may be considered as "steep." From the gradients thus estimated, by combining the telegraphic records of pressure with the distances between the stations, conclusions are drawn as to the probable force and direction of the wind. The force of the wind will generally not exceed the figure of 5 or 6 on the Beaufort scale (a "fresh" or "strong" breeze), unless the gradients be as high as 0·02 inch; and practically no storm of serious extent is ever felt over the United Kingdom unless there be a barometric difference exceeding $\frac{1}{2}$ an inch between two of our stations. This, however, does not preclude the possibility of dangerous squalls occurring in connection with thunderstorms.

It must be understood that the difference of the barometer readings at two places, when divided by the number of fifteens in the distance in nautical miles between them, does not give the gradient unless the line joining them happens to be *square* to the isobars, which would only exactly happen by chance. Any person wishing to ascertain the amount of a gradient must plot the isobars on a map, and measure, by aid of a scale, the distance betwen the isobars before proceeding with his calculations. For

instance, isobars may run through Oxford and Dover, which places are 120 miles apart as the crow flies, but the *isobars* will be *less* than 120 miles apart, unless they traverse England through Oxford and through Dover from S.W. to N.E. If the isobars traverse England from W. to E., conforming to the parallels of latitude, the distance between the isobars might, in the given case of Oxford and Dover, prove, for meteorological purposes, to be no more than 80 or 90 miles apart.

The reader will now be in a position, perhaps, to take in a little more with regard to the relations which have been found to subsist between wind and isobars. It is not sufficient, however, to realise that the force of the wind depends only on the closeness, and the direction of the wind on the lie or trend of the isobars. When the matter is studied with careful attention to details, it will be found that the shape or configuration of the lines is of primary importance. Although the shape of the isobars is perpetually changing, they may, with rare exceptions, be brought under one of seven well-defined forms, to which conventional names have been given, names which newspaper readers will constantly have under their notice, without, it may be, understanding them properly.

These seven forms are:—(1) the *Cyclone*, an area of low pressure bounded by circular or oval isobars; (2) the *Secondary Cyclone* (generally termed a "Secondary"), a small circular depression, or a loop in an isobar subsidiary to a primary cyclone; (3) the *V-shaped depression*,

an area of low pressure, bounded by V-shaped isobars, something like a secondary, but differing from it in many important particulars; (4) the *Anti-Cyclone*, an area of high pressure, the converse of the cyclone, also, however, bounded by circular or oval isobars; (5) *Wedge-shaped isobars*, an area of high pressure, bounded by isobars, converging to a point like a wedge; (6) *Straight isobars*, a barometric slope, down which the isobars succeed one another in nearly parallel lines; (7) the *Col*, or neck of low pressure, lying between two adjacent anti-cyclones.* Of these seven forms, the Cyclone, the Secondary, the V-shaped depression, the Anti-Cyclone, and the Wedge are the most important; whilst those who do not wish to go even thus far into details will find plenty to occupy their attention in the study of cyclones and anti-cyclones.

Some definitions respecting cyclones may first be given. The "centre" of a cyclone is the geometrical centre of the innermost isobar. The "diameter" is a line drawn through the centre as far outwards as the curveture of the isobars is distinctly related to the centre. A cyclone may have any diameter from 100 to 3000 miles. The commonest are between 1000 and 2000 miles. The "axis" of a cyclone is an imaginary line something like (but seldom exactly) vertical to the Earth's surface, round which the whole mass of air of a cyclone may be supposed to circulate. The "intensity" of a cyclone is mea-

* The reader who has travelled in Switzerland will have no difficulty in realising the import of this definition by remembering what a "Col" amongst the Alps is.

sured by the maximum steepness of the gradient in any part of it. If this exceed 0·02 inch per 15 nautical miles, then the cyclone may be considered to be of considerable intensity. The "level" of a cyclone means the barometrical reading at the lowest point. If this lowest point is higher than 29·9 inches, the cyclone may be called a high-level one. Below that it would be a low-level one. The "path" of a cyclone is the route followed by its centre. In England, by far the greater majority of cyclones move towards some point on the E. side of the compass, the most frequent direction being about E.N.E.

The "velocity" of a cyclone is the velocity of the centre. It may be anything from 70 miles an hour Eastwards to 10 miles an hour Westwards. About 20 miles Eastwards is an ordinary velocity, but sometimes a cyclone is stationary. This velocity of 20 miles an hour Eastwards is only the arithmetical mean of many observed; it represents no physical law.

The "trough" of a cyclone is a line drawn through its centre, generally at right angles to its path, which marks out the position of all the places where the barometer has sunk to its lowest point. Everywhere the mercury is falling in front of and rising in rear of this line in consequence of the forward motion of the cyclone; and this line defines the front and rear of a cyclone. The right and left sides of a cyclone are the right and left sides to an observer looking in the direction in which the cyclone is advancing.

The "life" of a cyclone is measured by the

number of days during which it can be traced on the charts. This may vary from less than one day to more than a fortnight.

The temperature of the air is always higher in front of than in rear of a cyclone; and, moreover, the warm air in front has a peculiar close, muggy character, independent of what may be the indication of the thermometer. The cold air in the rear has a peculiarly exhilarating feeling, also quite independent of the thermometer. When a cyclone moves Westwards (a rare event) the front temperature may not be absolutely higher than the rear, but, relatively, the wind in front, although N.W., will be warm and close, while the wind in rear, although S.E., will be cool and bright. The front, especially the right front, of a cyclone is always very damp, while the rear is dry to a marked degree.

The first symptoms of the approach of a cyclone of the most common type to an observer in the left or N.E. front is a halo, with a gradual darkening of the sky till it becomes solidly overcast, or else light whisps or barred stripes of cirrus cloud moving sideways appear in the blue sky, and gradually soften into a uniform black sky of a cumulo-stratus type, that is to say, a cloud* which extends in a flat layer, but is also to a certain extent gathered into lumpy masses. Nearer the centre, light, ill-defined showers fall from the uniformly black sky; the wind, from some point between S.E. and N.E., blows uneasily, and though the air may be cold and chilly, there

* The various forms of cloud will be stated and defined in a subsequent chapter. (See pp. 146-157 *post.*)

is an oppressive feeling about it. This state of things continues till the barometer commences to rise, when the weather at once begins to alter. In a cyclone where the steepest gradients are somewhere to the N. and E. of the centre, whilst the general character of the weather is as above described, it is more severe, the wind rising at times to a heavy gale, and the ill-defined showers developing into violent squalls.

In an approaching cyclone, where, as first mentioned above, the steepest gradients are S. of the centre, the first symptoms in the right or S.E. front are likewise a gradual darkening of the sky into the well-known pale or watery sky, with the air muggy and oppressive; or, in the alternative, whisps of cirrus first appear, the sky eventually becoming quite overcast. Nearer the centre, rain, usually in the form of drizzle, sets in, and the wind, from some point between S.E. and S.W., varying in force according to the steepness of the gradients, drives the cloud and rain before it. But this wind, differing from that in other portions of the cyclone in its way of blowing, does not for the same velocity raise so high a sea, or seem to bear so much down on the surface of the Earth. In cases of very great intensity the rain in this portion of a cyclone may come in showers, or even squalls, but its general character as a drizzle is never lost.

The general character of the W. or rear side of a cyclone of the normal type is a cool, exhilarating feeling in the air, with a high, hard sky disposed to break into detached masses of cloud. The rain which occurs near the centre is usually in

cold sharp showers, and the general hard look of the weather is in marked contrast to the dirty appearance of the weather which characterises the whole front of a cyclone. Further from the centre, showers or squalls are replaced by detached masses of cloud; these become scarcer and scarcer, until they finally disappear, leaving a blue sky. The wind, which is usually from some point between W. and N., blows in gusts, and for the same velocity raises a higher sea than a S.W. wind, and seems to bear down more on the surface of the water. The whole rear of a cyclone partakes of this general character, but the change of weather along the N. side is not so strongly marked as along the S. side.

Though the general characteristics of a cyclone —warm, muggy, and dirty weather in front; cool, dry, and bright weather in rear—are invariably maintained, yet individual cases vary much in detail, depending upon the type, the intensity, the size, local variation, diurnal variation, and seasonal variation—matters involving technical details which would be rather beyond the scope of this work. It may, however, be remarked that local circumstances form an especially important factor in the modification of cyclones. Amongst the local features which may be noted as influential are ridges of hills, forests, lakes, bare and open ground, and sea. The presence or absence of these modify in no small degree the normal features of a cyclone. So important is the position of the sea, that on the E. coasts of England the worst weather is with Easterly wind, whilst on the S. and W. coasts the worst

weather is with a Westerly wind. Seasonal variation shows itself in contrasts between the cyclones of winter and summer. Winter cyclones are usually much larger than summer ones; and even in cyclones of about the same size and intensity, the relative position of the rain and cloud areas is not quite the same. Moreover, in winter the clouds and general appearance of the sky are usually softer than in summer, and the rain is more drizzly and less showery.

A very noticeable point about cyclones is the tendency of their centres to follow a coast line rather than to strike inland. And when they do cross the land, they seem to follow lines of valleys, or, at any rate, low ground, as if such were lines of least resistance to cyclone motion. Speaking as regards the British Isles, cyclone centres have a tendency to pass up the English Channel or round the N.W. coasts of Ireland and Scotland. When they cross Scotland they not unfrequently follow the line of the Caledonian Canal.

A "secondary" cyclone is a small cyclone formed on the side of a larger one, almost invariably along the prolongation of the trough of a primary cyclone; or else on that side of the primary which adjoins the area of highest adjacent pressure. The most important feature about them is the manner in which they deflect the isobars of the primary, so as to leave an area of slight gradients and light winds on the side of the secondary next the primary, and a line of steeper gradients and stronger winds on the side farthest from the primary. Their motion is

usually parallel to that of the primary. In forecasting, the principal indications of secondaries is rain without much wind, and thunderstorms in summer; and their sudden formation very often unexpectedly disturbs and viciates the previous forecasts.

Allied to secondaries are V-shaped depressions, so-called because the isobars enclosing the low-pressure run into a point like the letter V. They are generally formed along the Southern prolongation, or the trough of a cyclone, or in the *col* or furrow of low-pressure which lies between two adjacent cyclones. Their motion is generally Eastwards along with their associated cyclone, but they are often very short-lived, lasting hardly a whole day; indeed, seldom as much as a day. They are distinctly non-cyclonic, and have their own special features of wind and rain, the wind in any part rarely rising beyond a strong breeze. The rainfall will be of uncertain duration and amount.

After the cyclone, the most important weather feature depending on isobars is the anti-cyclone, so-called because it is in every sense the converse of the cyclone. Whilst cyclonic isobars enclose an area of low-pressure with rain and strong winds, which circulate in a direction contrary to the hands of a watch (the whole system being generally in rapid motion), anti-cyclonic isobars enclose an area of high pressure which is associated with fine weather, and light winds, circulating with the hands of a watch, or no winds at all, the atmosphere being quiescent; and the whole system is usually stationary for

several days together. The isobars are more or less oval, approximating to a circle, and the gradients very slight. In the centre there is a dead calm; and while the winds at a distance circulate round the centre in the direction of the hands of a watch, they are a little out-curved (or centrifugal), thus forming another contrast to cyclones where the wind is always slightly incurved (or centripetal). The temperature under an anti-cyclone is always below the average of the season, and though in summer the Sun may be very hot, there is usually a coolness in the air in shade, whilst the nights are chilly. Extreme dryness is a marked normal feature of an anti-cyclone, though slight showers are not uncommon. The detailed circumstances of an anti-cyclone will vary somewhat with the season of the year, but the constant characteristics of a cold dry air and fine still weather are never absent. These characteristics will, in winter, often engender fog. The habitual calm (or only slight winds) which mark an anti-cyclone greatly promote terrestrial radiation, resulting in summer in a succession of hot days, and in winter in a succession of cold nights. Taken generally, the advent of an anti-cyclone indicates considerable continuance of settled fine weather.

"Wedge" isobars consist of isobars converging to a blunt point, but enclosing an area of high pressure instead of one of low pressure, as in the case of the V's. In every way "wedges" are the converse of V's, as anti-cyclones are of cyclones. These "wedges" seem to shoot up

in front of cyclones and V depressions, and to travel along before them.

On the front, or E. side, the weather is bright and the sky clear; the wind is N.W. and moderate, while the temperature is that due to excessive radiation. According to the season, this results by day in a peculiar burning heat which sometimes precedes rain, and by night in a white frost, which is another well-known sign of rain. On the rear, or W. side, where the barometer begins to fall, the wind turns to S.W., and the sky becomes overcast, with, very often, a halo round Sun or Moon as the cyclone draws near. Thus, as the wedge travels Eastwards, the sequence of the weather at a given place will be from very fine with N.W. wind, falling calm, to halo and gloom, with a S.W. wind, followed by rain, and perhaps a gale if the gradients of the on-coming cyclone are sufficiently steep.

Isobars "straight," or nearly so, are sometimes found at the edges of anti-cyclones, especially on the N. side. They are never very lasting, and the area which they have occupied is usually soon traversed by a cyclone of greater or less intensity. For purposes of forecasting, the indications afforded by straight isobars are cool, cloudy, unsettled weather, with wind, moderate to fresh (according to the gradients), to be followed soon by rain as a cyclone forms or comes up.

CHAPTER V.

THE BAROMETER.

It is not the object of the present and next following chapters to furnish the reader with a mere historical account of all the various meteorological instruments in use, still less to deal with the different varieties of instruments which have been proposed for the different classes of observations which require to be carried out in a fully-equipped meteorological observatory. There are many observers of the weather who would find pleasure and profit in elementary observations on the pressure of the air, on its temperature, on its moisture, and on the rainfall of the place where they live. It is for the tastes of such persons which I now propose to cater by giving some general account of the barometer, the thermometer, the hygrometer, the rain-gauge, the weathercock, and perhaps one or two other popular instruments. Though a professional meteorologist will require other instruments, as well as instruments of a much more elaborate and expensive character than those needed by the ordinary amateur, yet comparatively inexpensive examples of the five instruments above named are really sufficient for all common everyday purposes.

The barometer, as its name implies,* is intended to measure the downward pressure of the Earth's atmosphere on the Earth itself. Just as,

* *βαρός* weight, and *μέτρον* a measure.

for instance, a heavy iron weight thrown down on the surface of a grass field presses upon the grass and consolidates the soil underneath, so does the air press upon the soil and water which together make up the surface of the Earth. Between these two sorts of pressure there is no difference of principle, only that the potential effect of the mass of iron on the grass is palpably visible to our senses, whilst the effect of the pressure of the air cannot be said to be palpably visible.

The principle upon which the barometer is constructed is extremely simple. It is an instrument which counterbalances a column of air 40 or 50 miles in height, and of a diameter equal to its own tube. Let us suppose that this tube is $\frac{1}{2}$ inch in diameter; if we were to weigh a column of mercury $\frac{1}{2}$ inch in diameter and about 30 inches in height, and if it were also possible directly to weigh a column of air $\frac{1}{2}$ inch in diameter and 40 or 50 miles in height, we should find that the weight of these columns would be equal, and in opposite pans of a balance would equipoise each other.

This statement can be put to an indirect kind of test in the following manner:—Take a glass tube about 30 inches long, closed at one end, and fill it with mercury; place the open end in a cup containing mercury, keeping the finger pressed tightly against the open end until it is quite immersed. Erect the tube and withdraw the finger, keeping the open end of the tube all the while below the level of the surface of the mercury in the cup. It will then be found that

the mercury will not run out of the tube, because the pressure of the superincumbent air acting upon the surface of the mercury in the cup will sustain in position the mercury which is in the tube. Should the pressure of the atmosphere diminish, the fact will soon become known by the depression which will take place in the level of the column in the tube. If we employ for this experiment a tube say 36 inches in length, and, after filling it, plunge it into a cup of mercury in the way stated above, it will be found that the mercury in the tube will at once run out until the height of the column becomes reduced to about 29 or 30 inches, thus clearly proving the accuracy of the above reasoning.

It is only necessary for our present purpose to deal with the elementary principle involved in the construction of the barometer. A manufacturer has of course to take various practical precautions if he would produce an instrument of the highest accuracy and delicacy. It is of special importance that the mercury used should be free from impurities, the presence of which would viciate the results of the observations. In a crude state mercury contains varying quantities of lead, tin, and sometimes zinc, and these must be removed by suitable treatment. It is also necessary that both the interior of the tube and the mercury should be perfectly dry, and that all atmospheric air should be expelled from the interior. The expulsion of air, which is indispensable for a first-class instrument, is effected by boiling the mercury after it has been

placed in the tube. This is an operation of great delicacy and difficulty, often resulting in the tube being broken.

It all depends upon the purpose for which a barometer is intended to be used, whether it is constructed with merely the ordinary care shown by every good workman, or with a laborious and painstaking attention to every petty detail of the most delicate character. When a barometer is only intended as an ordinary weather glass, it is, of course, only constructed with ordinary care. Such an instrument, good enough for popular purposes, may be had for £2 or £3, or even less, but a standard instrument of the highest quality, such as would be provided in a public observatory, costs £20, or even more.

Fig. 8.
THE UPRIGHT MERCURIAL BAROMETER.

The following is a description of a first-class standard barometer. It is on Fortin's principle, reading from an ivory point in the cistern to ensure a constant level. The tube is enclosed for protection in a tube of brass extending throughout its whole length. In the upper portion of this tube are two longitudinal openings opposite each other, so that the surface of the mercury may be visible through its ordinary extremes of elevation or depression. On one side of the front opening is the scale of inches which reads by a vernier to $\frac{1}{500}$th of an inch: on the

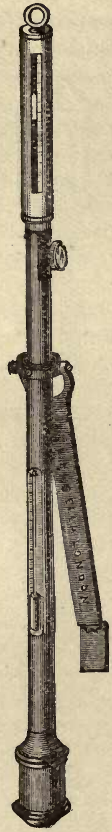

FIG. 9.—THE MARINE BAROMETER.

opposite side is sometimes placed a scale divided to show French millimetres, and reading also by a vernier to $\frac{1}{10}$th of a millimetre. The reservoir or cistern which holds the mercury is of glass, closed at the bottom by a piece of leather, acted upon by a thumbscrew passing through the bottom of an arrangement of brass which serves to protect the reservoir. Fortin's barometer differs from an ordinary one in the plan adopted for bringing the lower level of the mercury exactly to the zero point before reading off an observation. It may be described as a Torricellian* barometer, in which the bottom of the cistern can be raised or lowered by a screw. An ivory needle points downwards, and the extremity of this is on a level with the zero scale. Before taking an observation, the bottom of the cistern is raised or lowered by the screw until the point of the needle and its image exactly coincide.

Other forms of mercurial barometer in common use are the Syphon barometer and the Wheel barometer. The former name explains itself, the instrument consisting of a tube bent into the form of a syphon, having the same diameter at the lower as at the upper end.

* The meaning of this expression will be explained presently

The Wheel barometer was originally invented more than two centuries ago by the famous Robert Hooke, and is the instrument which is so frequently met with as a piece of furniture in old houses which were furnished half-a-century or a whole century ago. Our grandfathers and grandmothers admired its large round dial, and placed implicit confidence in the dogmatic phrases engraved upon it, but it is an instrument of the smallest possible scientific value. Indeed, its only merit seems to be the fact that the arrangement of the mechanism of the index causes comparatively minute variations of the mercurial column to give rise to a considerable sweep in the tip of the index, but it is also easy to see that with so much material intervening between the surface of the mercury and the index, the chances of error arising from friction, from the stretching of the cord which moves the index, from the liability of the cord to get off the pulleys, and other such like causes, must be considerable. It may be remarked in passing, that in order to preserve the outward form of the "Wheel" barometer, and thereby do homage to the Conservatism of the English mind, Aneroid barometers (now about to be described) are often sold mounted on

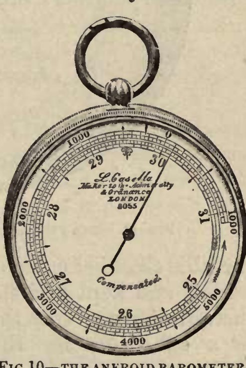

FIG.10—THE ANEROID BAROMETER

frames to resemble the old-fashioned "Wheel" barometer.

The Aneroid barometer, now widely known and used, is an ingenious mechanical contrivance* for indicating changes in the pressure of the atmosphere. The theory of its action depends on the effect produced by this pressure on a flat circular

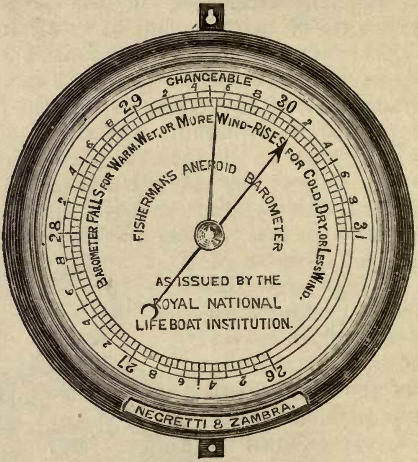

FIG. 11.—THE FISHERMAN'S ANEROID BAROMETER

metallic chamber exhausted of air and hermetically sealed, and kept in a state of tension by a strong metallic spring: thus the chamber with the spring is a substitute for the Torricellian tube, and the vacuum for the column of mercury. The

* As its name helps to indicate: α without, and νηρός wet (or fluid).

external appearance of the instrument is not exactly unlike that of a ship's chronometer. On the dial plate is a curved scale graduated to represent inches from 28 to 31. The pressure on the interior vacuum chamber is communicated by a system of delicate levers to an index or clock hand placed above the face of the dial, and thus minute changes in the atmospheric pressure are (by being *multiplied*) promptly rendered perceptible to the eye of the observer.

The Aneroid barometer though not an independent instrument (because it requires originally to be set and afterwards occasionally to be verified by a standard mercurial barometer) is by reason of its compactness, portability and general accuracy much approved of as a weather glass. The aneroid was invented by M. Vidi of Paris in 1847, and an exhaustive series of experiments carried out in the following year by Dent showed that a good aneroid would yield results identical with a mercurial barometer to within $\frac{3}{1000}$ of an inch.

Various forms of self-registering barometers have been devised. The most important of these is that in which photography and clockwork play the principal parts. Sensitised paper is arranged to pass, by steady clockwork movement, in front of the vacuum of a mercurial barometer, on which is directed the light of a lamp; in this way a sinuous streak is marked on the paper, and by suitable means the varying elevation of the mercurial column is made apparent, and can be reduced to numerical expression. An apparatus of this kind is in use at the Royal Observatory,

Greenwich, and in other such like establishments. A common and comparatively simple form of

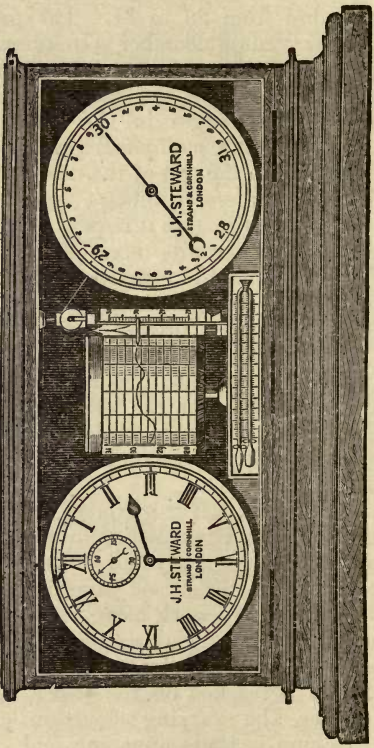

Fig. 12.—Self-registering Barometer.

self-registering barometer is represented in fig. 12, which is an instrument which may be said

to be suitable for popular purposes if its price (about £25), is not a bar in the way of a purchaser. The instrument figured consists of an aneroid barometer, having a large vacuum, which is very sensitive, and with graduations on the dial which are on a larger scale than usual, reading as they do to $\frac{1}{100}$ of an inch. The clock is an 8-day one. The dials of the clock and aneroid are both 8 inches in diameter. Between the clock and the aneroid a cylinder, 4 inches in diameter, is placed in a vertical position. The lower part of the cylinder is furnished with a toothed wheel, so constructed that it works into an endless screw, which is attached to the mechanism of the clock at the back, and by means of which the cylinder is caused to revolve. Close to the cylinder there is mounted a vertical scale corresponding to the barometric inches of the aneroid dial. A metal carrier with a pencil is connected by a delicate chain to the mechanism of the aneroid. The barometric changes taking place in the aneroid, and indicated to the eye by the usual pointer on the dial, are reproduced in a lesser degree by the pointer which moves up and down the vertical scale. Suitable mechanism connecting the vertical scale with the clockwork causes the pencil every hour to press against a paper chart which, attached to the revolving cylinder, is divided to correspond with the barometer scale; and thus records both the amount of the atmospheric pressure at the moment of observation, and the changes which occur from hour to hour and day to day during the seven days for which the charts are graduated, and the clock will go without

winding. For ordinary use the clock has a pendulum, but it is made with a lever movement when it is desired to set up the instrument to record barometric changes in places where a pendulum could not be employed; for instance, on board ship.

Though mercury is the liquid almost universally used in the construction of tube barometers, it may be observed that any liquid will answer the purpose, though not equally well with mercury. Mercury possesses two great advantages over all other liquids, and it is this fact which has led to its practically universal employment in the construction of tube barometers:—(1) That it does not give off vapour at ordinary temperatures; and (2) That its specific gravity is so much greater than that of any other liquid.

If mercury did give off vapour readily, it is evident that the space above the column would be filled with vapour, which would press downwards against the column, so that its weight would no longer be a measure of the atmospheric pressure, but of the difference of this pressure, and the elastic force of the vapour given off. In consequence of the specific gravity of mercury being so very great, the height of the column required to counterbalance the atmospheric pressure is comparatively small, and so barometers in the construction of which mercury is employed are not of inconvenient size. So far as material is concerned, there is nothing to prevent the construction of a tube barometer with water as the barometric material, but such a barometer would have to be theoretically

about 33 feet long. This follows from the fact that the usual atmospheric pressure is represented by (say) 2 ft. 6 in.* of mercury, and the specific gravity of mercury is about $13\frac{1}{2}$ times that of water, and 2 ft. 6 in. $\times$ $13\frac{1}{2}$ = $33\frac{3}{4}$ ft. In practice, owing to the presence of air, and to mechanical difficulties, the height of a column of water in a water barometer would actually stand at less than 28 feet. In point of fact, for the reasons already given, and for others which are obvious enough, nobody would nowadays seriously contemplate the construction and use of a water barometer.

Mention may here be made of a very useful and interesting, albeit still very unhandy, form of instrument, namely, Jordan's Glycerine Barometer, the invention of Mr. J. B. Jordan of the Royal School of Mines, Jermyn Street. This instrument is in principle essentially a mercurial barometer, in which glycerine is substituted for water or mercury. The specific gravity of glycerine, compared with mercury, is such that a column of glycerine about 27 *feet* long is required to do the work of 30 *inches* of mercury: the result is that a rise and fall of one inch in a mercurial column is represented by 10 inches in a glycerine column, so that changes

* The average height at which the mercury stands is taken in the text at 30 inches for simplicity of calculation, but it may be well to remind the reader that at the sea level it will be found to fluctuate between 28 and 31 inches; whilst in ascending high mountains it will fall to 20 inches and less. Thirty inches may, however, be taken as a sort of standard average height for England, though Admiral Fitz-Roy fixed it at 29·95 inches for London.

of very small and almost invisible amount in a mercurial column are rendered very distinctly visible in a glycerine column. Where space in a house is available, and expense and trouble are not deemed obstacles, a glycerine barometer is certainly a curious and interesting philosophical instrument.

When mercury is at a temperature of 32° F. the weight of one cubic inch is 0·491 lbs. From this we can calculate how many pounds on the square inch is the pressure of an atmosphere which corresponds to a barometric column of 30 inches. Let us suppose, for the sake of simplicity, that the area of the cross section of the mercurial column is one square inch, the atmospheric pressure will then be equal to $30 \times 0{\cdot}491 = 14{\cdot}73$ lbs., or, in round numbers, 15 lbs. to the square inch. When the elastic force of a gas or vapour is very considerable, it is usual to estimate it in so many atmospheres; thus, when steam is said to have a pressure of 5 atmospheres, it means that its elastic force is such that it would sustain a column exerting a pressure of 73·6 lbs. ($14{\cdot}73 \times 5 = 73{\cdot}65$) on the square inch. The fact that the Earth and everything on it is constantly subject to a pressure of 15 lbs. on every square inch, does not come home to us in daily life except with the assistance of an air-pump to take the pressure off, and show how things collapse when that is done.

The history of the circumstances that led to the discovery of the barometer is of peculiar interest. It appears that the constructors of a pump made for the Duke of Florence found

themselves unable to make the water rise higher than 32 feet or thereabouts when the air was exhausted from it. They applied to the celebrated philosopher Galileo for an explanation, and he contented himself by repeating the Aristotelian dogma, that "nature abhors a vacuum." This reply satisfied the pump-makers, though it did not, as far as we can tell, altogether satisfy Galileo, and there is reason to believe that he abandoned the idea before his death. It is, however, to his pupil Torricelli that we owe the first public acknowledgment that the phenomenon would be correctly explained by supposing it due to the counterbalancing of the 32 feet of water by the pressure of the atmosphere. He saw that if it be a weight of air which counterpoises 32 feet of water, then it must follow that, by the substitution of mercury for water, in consequence of its greater specific gravity, a column shorter than 32 feet, in the approximate ratio of 14 : 1, would answer equally well. Torricelli tried the experiment, and found that a column of mercury 2 feet 4 inches in height would counterpoise the pressure of the atmosphere, thus proving beyond a doubt that the explanation he had given was the true one.

Torricelli died in 1647, leaving his discovery not quite complete; for though he had ascertained that the weight of the water and the weight of the mercury was a counterpoise of something, most probably the weight of the air, yet that was not absolutely certain. The subject was taken up in England by Boyle, and in France by Pascal, Mersenne, and others The former,

by means of the air-pump, was enabled to try the barometer with air of different degrees of density. Pascal in another way effected the same object. In 1647 he suggested the idea that if the mercury were really sustained by the pressure of the atmosphere, it would necessarily fall in ascending a high mountain. Though illness prevented Pascal himself from personally establishing this fact, his relative, Perrier, undertook to do it for him. Accordingly, an expedition, headed by the latter, started on September 19, 1648, to ascend the Puy-de-Dôme in Auvergne. They found the result precisely as Pascal had foretold, and this finally settled the question. Similar experiments were carried on in England soon afterwards, and with, of course, an identical result.

There is a phenomenon sometimes to be noticed in connection with mercurial barometers which, from its singularity, deserves mention. Sometimes when the mercury is shaken a luminous appearance becomes visible in the vacuum This barometrical light, as it has been called, is sometimes diffused all over the vacuum; at other times it is confined to near the surface of the mercury. Its nature is unknown, but it has been suggested that it is electrical, though no satisfactory reason has been assigned for its appearing in some barometers and not in others, and for its appearing and disappearing from time to time in the same instrument. It was first noticed by Picard two centuries ago.

In taking barometer observations with great nicety it is necessary to apply certain corrections for temperature, capillarity, index-error,

and elevation above the sea-level. The last-named often becomes of considerable importance. so it will be alluded to again hereafter.

CHAPTER VI.

THE THERMOMETER.

Of the various philosophical instruments which are in the hands of that remarkable body, "the general public," it may certainly be said that none is so widely known as the thermometer; perhaps widely disseminated would be a preferable expression, for it may be doubted whether one in ten of those who use these instruments know anything about their theory or practical nature.

Any discussion as to the physical character of heat in its general relations would be beside the object now in view. We must take heat as we find it, and see how it can be approached so as to deduce useful facts. We can obtain in a variety of ways crude ideas in reference to it. For philosophical purposes, the expansion it universally causes in all natural substances affords a method of estimating it in a relative sense. Everybody knows by experience that a pair of boots which are a perfect fit in the month of January, if *get-on-able* in July, can only be worn with greater or less inconvenience and discomfort. Why? The reason simply is, that the natural heat of the

summer season causes additional perspiration and an increase in the bulk of the foot, and this can only be accommodated by an enlarged boot, except the wearer make up his (or *her*) mind to endure torture for fashion's sake, as many in fact do. Another familiar effect of heat is well known to the laundress. Her "box-iron" has its heater made much smaller than the case, in order that the former, when made red-hot to subserve the purposes of her calling, may yet be able to enter the latter. We might multiply illustrations of this kind to an indefinite extent, but the above are sufficient as an introduction to the following general proposition:—That inasmuch as all bodies whatsoever expand by heat and contract by cold, a thermometer is an instrument which applies the known expansion and contraction of one body in such a way that it may serve as a standard of reference with which to compare the expansion and contraction of other bodies.

The same body always has the same volume at the same temperature, and always suffers the same change of volume with the same change of temperature. Since volume and change of volume admit of exact measurement, they become a very convenient means for determining the change which takes place in the temperature of any body. Although all bodies are susceptible of dilatation and contraction by changes of temperature, yet all are not equally fitted for thermometrical purposes. For many reasons, some of which will presently be adverted to, mercury is found to be best adapted for the purpose.

A mercurial thermometer consists in its ordinary, or as we may call it, its typical form, of a capillary glass tube, say from 8 to 15 inches long; to one extremity of which (which when mounted, becomes the lower extremity) a glass bulb is blown, the bulb and part of the tube being filled with mercury. When such a tube is exposed to an increase of temperature, the glass and the mercury contained in it will both expand. If these expanded in the same proportion, the capacity of the bulb and tube would be enlarged in the same proportion as the mercury in them, and consequently the level of the mercury in the tube would remain unaltered. Considering, however, that the expansion of the bulb and tube are different from that of the liquid metal contained in them, the level of the column in the tube will, after expansion, stand higher or lower than before, according as the expansion of the mercury is greater or less than the expansion of the bulb and tube.

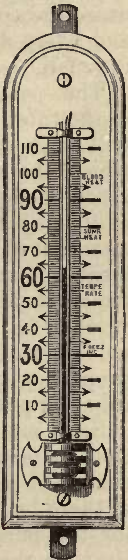

Fig. 13.
ORDINARY THERMOMETER

It is found by experiment that the dilatability or expansive power of mercury is greater than that of glass in the proportion of nearly 20 to 1; and, consequently, the capacity of the bulb and tube will be less enlarged than the volume of the mercury contained in them in the proportion of nearly 1 to 20; therefore, for the reason above

stated, every elevation of temperature by which the tube and the mercury would be affected, will cause the column of mercury to rise in the tube, and every diminution of temperature will cause it to fall.

The space through which the mercury will rise in the tube, by a given increase of temperature, will be greater or less according to the proportion which the diameter of the tube bears to the capacity of the bulb. The smaller the proportion of the one to the other, the greater will be the elevation of the column produced by a given increase of temperature; for a given increment of temperature will produce a definite increase in volume in the mercury, and this increase of volume will fill a greater space in the tube, in proportion to the smallness of the bore of the tube compared with the capacity of the bulb.

Such an instrument, without anything additional attached to it, would merely indicate, if a change of temperature took place, the simple fact of there being an alteration. To render it useful for the purposes of science, it is necessary that the tube should be provided with some accessary by means of which exact numerical indications of the amount of the changes might be obtained. If, therefore, a graduated scale is attached to the thermoscopic tube previously described, we shall possess a thermometer of the simplest form. Of course, in the actual construction of thermometers, there are many precautions to be attended to, which need not be adverted to here.

In making a thermometer, it is not indispensable that mercury should be used; air will, in

many cases answer the purpose. From the delicacy of its indications, and the regularity of its expansion, air would seem to be the material best fitted for measuring changes of temperature, and indeed, it was the substance first used. The early air thermometer consisted of a simple glass tube, having attached to it at one end a bulb, the other dipping into some liquid contained in a vessel below; as the bulb became heated, the included air expanded and forced down the liquid in the tube; as it cooled, the air contracted, and the liquid rose; a scale attached gave the amount of the corresponding variation in temperature. But the inconvenient size of the instrument, and the extreme delicacy of its indications, together with its limited range, impaired its utility. It was also found that differences of atmospheric pressure, entirely independent of temperature, caused an alteration in the bulk of the air; these, and other circumstances combined, ultimately led to the air thermometer falling into disuse.

The first great improvement in the thermometer was made by the Florentine Academicians; they substituted the expansion of a liquid for that of air, employing spirits of wine for the purpose, and they divided the tube of the instrument arbitrarily as before, by means of small dots of enamel placed at equal distances on it; but inasmuch as the scales of the different instruments were not formed upon any fixed principle, the results which they furnished did not admit of direct comparison. To obviate this evil Sir I. Newton, taking advantage of Hooke's observation, that ice always melted at a fixed tempera-

ture, and that under certain standard circumstances the boiling point of water is invariable, proposed the adoption of these as starting points, between which, and on either side of which, a scale of equal parts should be graduated as required. Though these two points were unanimously agreed upon as the points of reference to be employed, it unfortunately happens that the interval has been subdivided differently in different countries. In Great Britain, certain of the states of the Continent, and North America, the interval between the freezing and the boiling points is divided into 180 equal parts or thermometric degrees. The scale is prolonged by additional equal parts above the boiling and below the freezing points. The zero is placed at the 32nd division below the latter, so that on this scale the freezing point is 32° and the boiling point 212° ($32 + 180 = 212$). This method of graduation, known as Fahrenheit's, was adopted about 1724. It may be remarked in passing that the reason why the zero was placed at 32° below the freezing point was because that point indicated the lowest temperature then known to exist, namely, the most intense cold which had been observed in Iceland. Temperatures, both natural and artificial, very much lower than this, have been observed in recent times.

In France and other parts of Europe, the Centigrade division originally suggested by Celsius prevails. In this scale the interval between the two reference points is divided into 100° and the zero is placed at the freezing; temperatures below this being indicated by the

prefix of the negative sign—an extremely inconvenient arrangement in the practical use of the thermometer.

A system known as Réaumer's is used in Russia and parts of Germany; the interval between the reference points is divided into 80°. In another scale, formerly used in Russia, and known as De L'Isle's, from its having been invented by that physicist in 1733, the before-mentioned interval was divided into 150°, reckoned backwards from the boiling point. Since the number of degrees into which the interval between the freezing and the boiling points in the four systems is divided, are respectively 180, 150, 100, and 80, it follows that 9° Fahrenheit, $7\frac{1}{2}$° De L'Isle, 5° Centigrade, and 4° Réaumer are severally equal. The conversion of degrees upon one scale into those of another is easily effected by the aid of certain simple formulæ or tables, which will be found in many books treating of the subject in detail. Practically, the conversions which most frequently require to be made are between Fahrenheit and the centi-

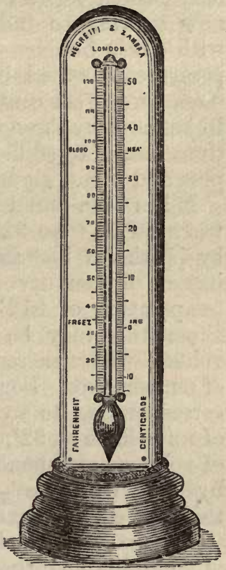

FIG. 14.—THERMOMETER WITH FAHRENHEIT AND CENTIGRADE GRADUATION.

grade scales. The former may be regarded as the established scale, and the latter the innovating one, pushed forward by the decimal gentlemen, now seeking to indoctrinate the English mind with their hobbies. In regard to winter temperatures recorded by means of centigrade thermometers, great confusion and risk of error have to be faced by those who have to analyse observations made by different persons, owing to the plus and minus signs.

It has been found by experiment that mercury when raised from 32° to 212° increases in volume by $\frac{2}{111}$ths of its value at 32°. Thus 111 cubic inches of mercury at 32° will, if raised to a temperature of 212°, become 113 cubic inches. From this may be deduced the increment of volume which mercury receives for each degree of temperature. For since the increase of volume, corresponding to an elevation of 180°, is $\frac{2}{111}$ths of its volume at 32°, we shall find the increment of volume corresponding to 1° by dividing $\frac{2}{111}$ths by 180, which is $\frac{1}{9990}$. It follows, therefore, that for each degree of temperature, by which the mercury is raised, it will receive an increment of volume amounting to $\frac{1}{9990}$th of its volume at 32°. It follows also that the weight of the mercury which fills that portion of a thermometer tube, representing 1° of temperature, will be the $\frac{1}{9990}$ of the total weight contained in the tube. We here assume that equal increments of heat produce equal dilatations of the mercury in the tube, and it has been found by careful experiments, that such is actually the case between the freezing and boiling points, but that at extreme

temperatures the mercury does not uniformly expand and contract. Since, however, the meteorologist is never called upon to consider extreme temperatures, I may pass over farther allusion to this matter.

It may be well here to mention in a summary form the reasons why mercury is so generally adopted for thermometric purposes. It is highly sensitive to changes of temperature, contracting and dilating quickly under the influence of varying temperature; it freezes at a low, and boils at a high temperature, and at temperatures which are not near these extremes, its expansive and contractive powers are very uniform. It does not vaporise and become broken up into small particles in so confined a space, nor does it change its bulk by adhering to the sides of the glass. These are the reasons which have led to its so extensive use. The freezing point of mercury being $-40°$ (*i.e.*, 40° below zero), and its boiling $+600°$ (*i.e.*, 600° above zero), a mercurial thermometer may be constructed to afford indications through a very long range of temperature.

It is not known when, and by whom, the thermometer was first invented; but in 1590, Sanctorius of Padua, constructed an air-thermometer. About the middle of the 17th century a great improvement was effected by Italian artists, who, under the direction of the members of the *Academia del Cimento*, made spirit-thermometers, as before-mentioned.

The idea of using mercury is said to be due to Halley, the astronomer, but according to Boer-

haave, it was Olaüs Römer—known to astronomers as the inventor of the transit instrument, and the discoverer of the motion of light—who first constructed a mercurial thermometer in 1709. It was, however, Fahrenheit, of Amsterdam, who perfected Römer's invention, by devising the thermometer which now bears his name. Breguet of Paris once constructed a thermometer founded upon the unequal dilatation of different metals. It was, however, more curious than useful.

It is of great importance in meteorology that the observer should be able to ascertain the highest or lowest point of the thermometric scale which the column of mercury may have reached during his absence, and several contrivances are in use to obtain a record of this kind.

Notwithstanding that the principles of its construction are not of the most exact kind, the instrument invented by James Sixe, of Colchester, in 1788, and hence known as Sixe's self-registering thermometer, may be pronounced an exceedingly useful one; perhaps on the whole the best for purely popular purposes, in which portability is not an object. It depends for its action on the unequal expansions of mercury and alcohol, and consists of a long glass tube, with bulbs at each end, bent twice in the same direction, and to such an extent that the three sections resulting from the double bending are parallel to each other. Mercury occupies the central portions of the tube, and alcohol the two ends. The tube is mounted vertically, and the

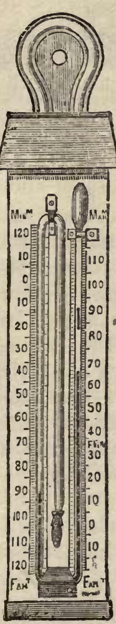

FIG. 15.
SIXE'S SELF-REGISTERING THERMOMETER (Common Form)

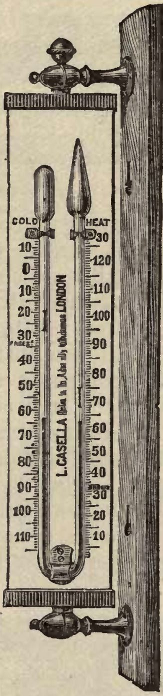

FIG. 16.—IMPROVED SIXE'S SELF-REGISTERING THERMOMETER

mercury is so arranged that it fills those portions of the tube adjacent to the lower bend. Steel indices slide up and down at each end of the mercurial column, and are shifted from time to time by means of a magnet when it is desired to "set" them ready for an observation. Fig. 16 represents an improved form of Sixe's self-registering thermometer in which the second bend in the tube is got rid of.

Another self-registering instrument in general use is Rutherford's. This consists really of two thermometers placed side by side in a horizontal position, one containing mercury, and the other spirit. In the former, which registers maximum temperatures, is placed a steel index, which is pushed forward by the mercury when the temperature rises, and which remains in that position when the column

recedes on the temperature falling. In the latter, which registers minimum temperatures, there is

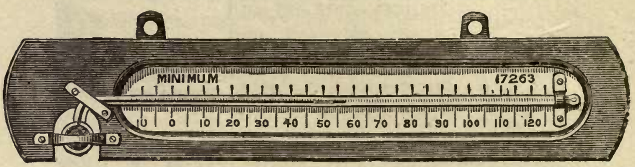

Fig. 17.—Rutherford's Self-registering Minimum Thermometer.

an index of ivory or glass with a flattened end which recedes with the spirit as it retires in the tube, but which in consequence of its shape does not return with the fluid on an increase of temperature taking place, the spirit easily passing by it. It is adjusted to its position at the end of the column of spirit by gently shaking the tube with the bulb end upwards. The chief drawback to this instrument is that in the course of time the steel index of the maximum thermometer gets clogged by the mercury owing to the oxidation of the steel.

We have now to speak of some single self-registering thermometers. Professor Phillips's for

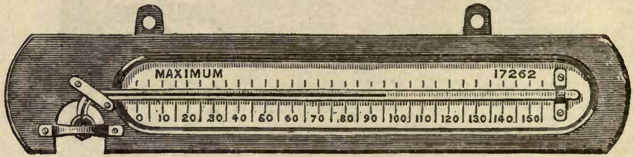

Fig. 18.—Phillips's Self-registering Maximum Thermometer.

maximum temperatures is an improvement on Rutherford's. It is a horizontal thermometer in

which a portion of the mercurial column is cut off from the main body by a bubble of air. When the temperature rises the whole column moves forward, but on falling, the detached portion which is beyond the air bubble remains stationary. The observer can thus at once see the extent of the rise. The instrument is set by a gentle tap.

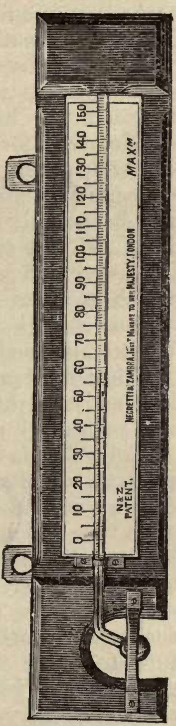

FIG. 19.—NEGRETTI AND ZAMBRA'S MAXIMUM THERMOMETER.

Negretti and Zambra's maximum self-registering thermometer resembles Rutherford's in outward appearance. During the process of construction a small piece of solid glass enamel is passed into the tube, which nearly fills the bore; this piece of glass is pushed down nearly to the bulb, and then the tube is bent at that part. When the temperature rises the mercury is forced past the obstruction, but when the temperature falls it cannot return, the contraction in the mercury occurring below the bend.* Thus the further end of the detached column shows the extent of the maximum rise. When a reading has been taken the instrument is reset by inclining it, bulb downwards, and giving it a gentle shake.

* The contraction in the portion cut off is too insignificant to require to be taken into consideration.

It must at all other times be protected from shakes or vibrations, or the weight of the detached portion of mercury will cause it to become automatically displaced, and the reading will be deceptive.

A good mercurial minimum self-registering thermometer has long been a meteorological desideratum, for it is obvious that comparisons of temperatures determined with two such opposite substances as mercury and alcohol cannot be entirely satisfactory. The ingenuity of Mr. L. M. Casella some years ago resulted in the invention of a mercurial minimum thermometer, which is described by Buchan as "a triumph of science and glass blowing," but too sensitive to be recommended for general use.

Other self-registering thermometers, both for heat and cold, have been devised, but none have met with much acceptance.

The *Solar-Radiation Thermometer* is a thermometer which has a blackened bulb, and a scale divided on the stem, the whole protected by a glass tube which acts as a casing. It is mounted horizontally on a stand which rests on the grass, and is exposed to the full rays of the sun, but sheltered from currents of air. The object of such a thermometer is to measure the temperature to which the surface of the earth (be it grass or soil) is raised by the direct rays of the sun.

The *Vacuum Solar-Radiation* thermometer differs from the preceding in being entirely enveloped in a glass tube and globe, from which the air has been exhausted. The object of this instrument

is to obtain a measure of the amount of the solar-radiation wholly freed from the casual effects of passing currents of air. Observations in different localities, or in the same locality under different circumstances, are thus comparable with each other, which is not the case when they are made with exposed instruments.

The late Dr. W. A. Miller, of King's College, gave the following as tests which a good thermometer should answer:—"When immersed in melting ice, the column of mercury should indicate exactly 32° F.; when suspended with its scale immersed in the steam of water boiling in a metal vessel (the barometer standing at 30 inches), the mercury should remain stationary at 212°. When the instrument is inverted the mercury should fill the tube, and fall with a metallic click, thus showing the perfect exclusion of air. The value of the degrees throughout the tube should be uniform. To ascertain this, a little cylinder of mercury may be detached from the column by a slight jerk, and on inclining the tube it may be made to pass from one portion of the bore to another. If the scale be properly graduated, the column will occupy an equal number of degrees in all parts of the tube."

Not one thermometer in fifty of those commonly sold in the shops will stand these simple and (if accuracy is really to be thought of) indispensable tests. In numerous shop windows stacks of thermometers may be seen, which though all in close proximity, indicate the most discordant results instead of perfect harmony or even respectable uniformity. Dr. Miller added the follow-

ing cautionary remarks:—"If a thermometer be graduated immediately after it has been sealed, it is liable to undergo a slight alteration in the fixed points of the scale, owing to the gradual contraction of bulb, which does not attain its permanent dimensions until after the lapse of several months. This contraction is probably due to the pressure of the atmosphere. From this circumstance the freezing-point may become elevated from $\frac{1}{4}$ to $\frac{1}{2}$ a degree; and thus the graduations throughout the scale indicate a temperature which is higher than the true one by the amount of the error. In some thermometers the bulb, as Pierre has shown, does not at once contract to its proper dimensions; and thus a temporary displacement of the graduation is caused every time such instruments are heated to 212°." Regnault found that some mercurial thermometers which agree in their indications at the freezing and boiling points, differ at intermediate positions; and that these differences frequently amount to several degrees, a circumstance which he thought might be due to the unequal expansion of different kinds of glass. Enough has been said to show the delicacy of these instruments, and it must be quite obvious that at such a price as one, two, or three shillings, it is impossible to manufacture an instrument with any solid claims to reliability for purposes of scientific record. Instruments of this character will indicate relative changes, but absolute values can only be obtained from carefully made (*i.e.* expensive) ones. It is therefore infinitely better for an intending meteorological

observer of limited means to concentrate his funds on the acquisition of one or two really good instruments in preference to seeking to obtain an imposing show of worthless ones, always supposing that he desires to work for the benefit of science—but I am digressing.

It will add to the completeness and usefulness of this chapter if I say a word on some less common forms of thermometers which are constructed for special purposes. Fig. 20 and fig. 21 represent two forms of "clinical" thermometer. A clinical thermometer is a very small and specially delicate self-registering maximum thermometer intended for taking and recording the temperature of the human body in cases of disease, or suspected disease, especially fevers. The temperature is usually taken by placing the bulb either under the tongue or under the arm-pit for a sufficient time to enable the mercury to rise as far as it will. It is not requisite, of course, for the thermometer to be read off whilst in contact with the patient's body, for it may be removed and laid aside until it is convenient to read off the indication furnished by the index.

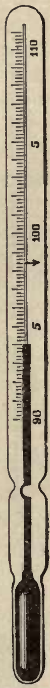

Fig. 20. The Clinical Thermometer.

Fig. 21 represents a form of thermometer as sold by Steward, which is designed expressly for the nursery and family use. It is so simple that it is scarcely possible for any one using it to fall into

a mistake, for there are only three marks on the tube. No. 1 stands at 73° F. for a tepid bath;

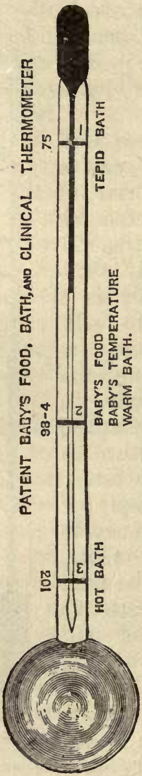

FIG. 21.—"THE BABY'S" THERMOMETER.

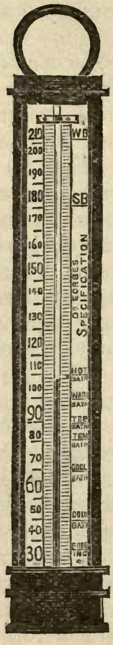

FIG. 22.—SPECIAL THERMOMETER FOR HOT WATER.

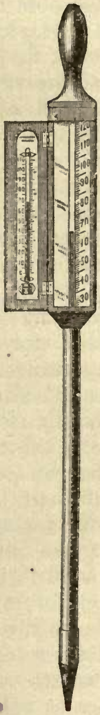

FIG. 23.—SPECIAL THERMOMETER FOR HOT-BED.

No. 2 at 98·8° for warm food, a warm bath and healthy normal temperature; No. 3 at 103° for

a hot bath, too hot for general use except under medical advice. If the baby is unwell, and its temperature approaches 103°, there is something seriously wrong, and a doctor should be consulted.

Figs. 22 and 23 represent special forms of thermometer mounted to subserve the special requirements of the brewer and the gardener. In point of fact, the so-called "Brewers'" thermometer is much the same as the common household thermometer, except that the bulb is encompassed by a water-tight cup which will hold a sufficient amount of hot liquid, whatever it may be, to enable the person using the thermometer to lift some of the liquid up to a convenient elevation above the surface of the main body for the thermometer scale to be examined with facility: and except that the graduations start higher, and run up much higher—that is, to a little beyond boiling point.

The gardener, by the use of his form of thermometer, can ascertain the temperature of the interior of his hot-bed (information often necessary to secure the welfare of his plants) by driving the point of the thermometer mount into the bed, and taking a reading so soon as the instrument has remained there for a sufficient period to acquire the temperature of the surrounding soil.

Last and also least (in point of size) may be mentioned "Immisch's Pocket Thermometer" represented in Fig. 24. It is quite a watch-pocket affair, but is extremely sensitive and accurate. A thermometer is often useful to a traveller, but the risk of carrying a mercurial

thermometer hundreds or thousands of miles packed with one's personal luggage is very great, and for such an instrument, Immisch's is, in a general way, a perfect substitute.

FIG 24 —IMMISCH'S POCKET THERMOMETER.

In carrying on observations with the thermometer (and the remark is equally true in the case of the hygrometer) it is very important that the thermometer should be properly placed; that is, in a situation where its results will not be vitiated by accidental circumstances. For instance, one often sees a thermometer nailed up against a brick wall facing South, and the contented owner, will say to his sympathising friends, "Dear me, the heat to-day is appalling: my thermometer is at this moment 116° in the Sun; this is quite tropical; no wonder we are all feeling the heat" No wonder, indeed! Yet the temperature of the air may be several degrees lower than it was the day before, but the day before our friend examined his pet instrument at a different hour, and the Sun was not shining on that brick wall, and the brick wall therefore was not storing up and distributing the truly tropical heat which the figures 116° if not delusive would imply.

To put the matter in another form, no thermometer reading is of any value to indicate

the temperature of the air unless it is so hung that the air has free access, and the direct rays of the sun have not free access so as to fall upon it. In other words every thermometer in-

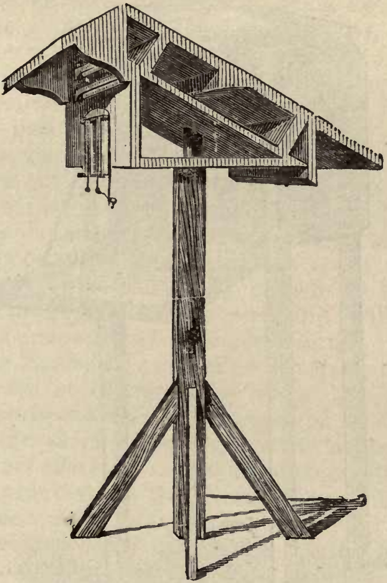

FIG. 25.—GLAISHER'S THERMOMETER STAND.

tended to be used in the open air must be sufficiently and suitably screened. If results of the highest value are desired, a properly constructed stand must be employed.

In Glaisher's stand, the bulbs of the thermometers all project below the edge of the

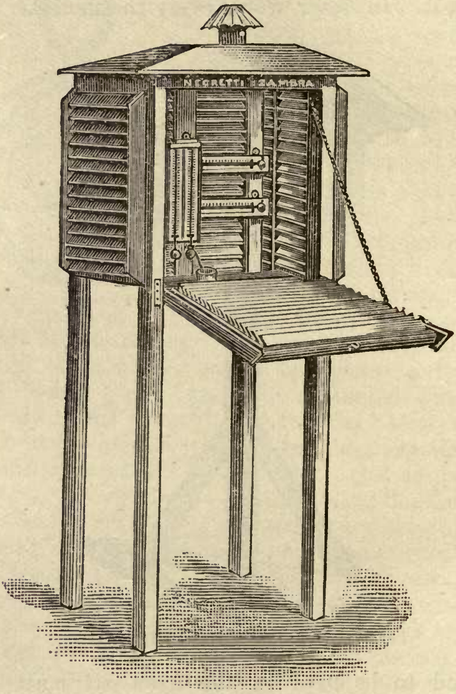

FIG. 26.—STEVENSON'S THERMOMETER STAND.

vertical board from which they hang, and so they are free to the air in all directions. The

whole of the upper structure revolves on a pivot in the upright post, so that the thermometers can be shifted at pleasure out of the reach of the direct rays of the Sun. This shifting should by rights be done more than once a day, and of course it must be done by hand, which is inconvenient. To obviate this, a screen known as Stevenson's was designed. In this there are double louvres which slope in opposite directions, so that whilst the air has free access to the instruments inside, rain and radiant heat cannot enter. The screen should stand on open ground with the door facing the N., and the door may be left down when the weather makes it safe to do so. The legs of the stand must be securely anchored to the ground by some suitable fastenings or the structure will be liable to be blown over in windy weather. The louvres of Stevenson's screen are generally made of wood, but sheet zinc is preferable, because it more quickly conforms to changes of temperature in the surrounding air, and so minimises the possible effects of radiation which might impair the readings of the thermometers inside. This screen must not be erected under the shadow of any trees nor within 20 feet of a wall.

CHAPTER VII.

THE HYGROMETER.

THE *Hygrometer** is an instrument designed to measure the amount of aqueous vapour contained in the atmosphere at any given time. The best for general use and also the simplest is the "Wet and Dry Bulb Hygrometer." This consists of two similar thermometers mounted side by side on a small frame, the bulbs of each being enveloped in some soft material, such as very thin flannel or cotton wick. One of these wrappers is required to be kept constantly moist by the capillary action of the wrapper, the lower end of which dips into a small vessel underneath containing water. The rapidity of the evaporation, and consequently the depression of the temperature of the moistened bulb will be greater in proportion as the atmosphere is free from moisture. The temperature of the dry and wet bulbs being known from observation, it is possible to ascertain the hygrometric condition of the atmosphere by means of tables which have been constructed for the purpose. The following is an abstract of

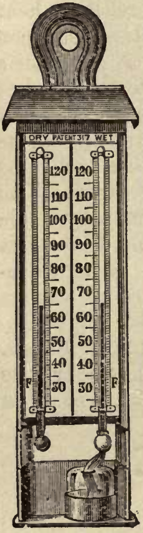

FIG 27.—THE WET AND DRY BULB HYGROMETER.

* 'ὑγρός, damp, and μέτρον, a measure.

such a table prepared many years ago by Mr. J. Glaisher, the eminent meteorologist.

Temperature of Dry Bulb (Fahrenheit).	Multiplier.	Temperature of Dry Bulb (Fahrenheit).	Multiplier.
° 10—16	8·7	° 51—55	2·0
17—20	8·0	56—60	1·9
21—23	7·5	61—65	1·8
24—26	6·5	66—70	1·8
27—28	5·3	71—75	1·7
29—31	4·1	76—80	1·7
32—35	3·0	81—85	1·6
36—40	2·4	86—90	1 6
41—45	2·2	91—95	1·6
46—50	2·1	96—100	1·5

Such a table as the above is to be made use of in accordance with the following Rule. Multiply the difference between the indications of the two thermometers by the multiplier given in the table opposite to the temperature corresponding to that of the dry bulb, and subtract the product from the temperature of the dry bulb: then the remainder will be the "temperature of the dew-point," as it is called, that is, the temperature to which the temperature of the air would have to fall in order that the air might reach a state of saturation, and dew be formed.

By another table also in use for the wet and dry bulb hygrometer, information is furnished by inspection as to the humidity of the air on the

assumption that complete saturation is indicated by 100.

TABLE OF DIFFERENCES OF DRY AND WET BULBS, AND THE HUMIDITY IMPLIED THEREBY.

Air Temperature by Dry Bulb.	Difference between Dry and Wet Bulbs.					
	2°	4°	6°	8°	10°	12°
	Humidity					
34°	79	63	50			
36	82	66	53			
38	83	68	56	45		
40	84	70	58	47		
42	84	71	59	49		
44	85	72	60	50		
46	86	73	61	51		
48	86	73	62	52	44	
50	86	74	63	53	45	
52	86	74	64	54	46	
54	86	74	64	55	47	
56	87	75	65	56	48	
58	87	76	66	57	49	
60	88	76	66	58	50	43
62	88	77	67	58	50	44
64	88	77	67	59	51	45
66	88	78	68	60	52	45
68	88	78	68	60	52	46
70	88	78	69	61	53	47
72	89	79	69	61	54	48
74	89	79	70	62	55	48
76	89	79	71	63	55	49
78	89	79	71	63	56	50
80	90	80	71	63	56	50
82	90	80	72	64	57	51
84	90	80	72	64	57	51
86	90	80	72	64	58	52

In the practical work of making and keeping observations with a wet and dry bulb hygrometer there are some precautions to be observed which must be mentioned here. The instrument must be exposed to the air quite in the shade, but protected from currents of air. The water reservoir should be as far removed as possible from the dry bulb, but it must be kept always fairly full, so as to ensure the wrapper which covers the wet bulb being always quite moist. When the water used for filling the reservoir is considerably charged with mineral matter such as lime there is a constant tendency to the pores of the wrapper becoming choked. The evil consequences of this in disturbing the accuracy of the readings can only be got over by washing the wrapper at frequent intervals (say fortnightly in extreme cases), and by having a new wrapper every two or three months.

The necessity for this frequency of change will be obviated to some extent by using distilled water, or clean rain-water, or even simple boiled water. All accumulations of dust or dirt, including starch or "dressing" of any kind, must be removed from every new wrapper before use, and, if needs be, from old wrappers when in use.

In thick, foggy weather, and in calm, cold weather, the wet bulb will often read *higher* than the dry bulb, because the air is perfectly saturated. In such cases the reading of the wet bulb must be set down as being identical with that of the dry bulb, or perhaps more properly no record should be made except the bare fact of the reading being void for the reason in question.

When the wet bulb is frozen it should be wetted with ice-cold water by means of a brush. The water will then freeze and cool down to the temperature of the air. After this the mercury in the wet bulb will sink to a little below the level of the mercury in the dry bulb, and so the temperature of evaporation will be ascertainable. When the temperature of the air rises above freezing-point, the ice should be removed from the wet bulb and wrapper by means of a little warm water.

The wet-bulb hygrometer is often spoken of as "Mason's Hygrometer," whilst the Germans call it the *Psychrometer*,* a name invented by August of Berlin, who revived its use in 1828. In point of fact it seems to have been invented, in a certain sense, by several meteorologists independently.

An instrument known as "Daniel's Dew-point Hygrometer" is sometimes met with, and is a very beautiful philosophical toy, but it is not suitable for practical purposes.

This is a convenient place in which to mention the fact that a meteorological instrument, properly so called, is not absolutely essential for the indication of changes in the hygrometric condition of the air. There are many substances to be met with in nature which are extremely sensitive to variations in the humidity of the atmosphere, all of which may be used as *hygroscopes*, or damp-indicators, though they cannot be employed as *hygrometers*, or damp-measurers, in the exact sense of the word.

* *ψυχρός*, cold, and *μέτρον*, a measure.

Amongst other substances may be mentioned wood, ivory, quills, hair, whalebone, animal membranes, whipcord, and catgut. The vegetable kingdom furnishes various hygroscopic mediums, such as the awn of the *Andropogon contortus* (Linn.), the Oobeena Hooloo, of Mysore; the *Avena fatua* (Linn.) or "wild oat"; the *Funaria hygrometrica*, or "common cord-moss"; and the arista of the seed of the *Stipa pennata* (Linn.), or "common feather-grass." The internal membrane of the *Arundo phragmites*, or "common reed," was used by Adie.

CHAPTER VIII.

THE RAIN-GAUGE.

THE measurement of the rainfall is made by means of an instrument called a *Pluviometer* * or Rain-gauge. The rainfall of a place is something more than merely a matter of scientific interest, for it is an eminently practical matter which closely concerns the interests of the whole community at large. In the critical days of spring, when the growth, or the contrary, of newly-sown seeds is of vital importance to everybody during the coming twelve months, it makes all the difference both to the labours and to the responsibilities of the gardener whether the rain which has fallen unknown to him by night is much or little; whether it will suffice for

* *Pluvis* rain, and *μέτρον*, a measure.

the necessities of his seeds and crops; or whether he must supplement it, or make good its entire absence by the artificial application of water to his ground. Accordingly it may be said that the prosperity and the convenient working of every garden, great or small, will be materially facilitated if its owner keeps a rain-gauge or has access to one near at hand. The question of rain or no rain is also a very important one to the hydraulic engineer as regards supplies of water to the reservoirs of water companies and to canals for canal traffic.

Any open vessel with upright sides which will hold water is in a certain sense available for use as a rain-gauge, and all we have to do is to notice the rain which has been collected in it and measure its vertical depth with a foot-rule. In England, however, rain does not fall in such a wholesale fashion (except in the English Lake District) as to render it reasonable to talk about "feet" in the measurement of it; rather it is a matter of fractions of an inch, and on rare occasions of one or two whole inches. Therefore, in dealing with the customary small rainfalls of this country, meteorologists use instruments specially contrived so that their mouths possess a known area; and what is received thereby will, when collected and poured into a suitable measure of capacity, indicate by means of a scale such minute falls as the $\frac{1}{100}$th of an inch in depth at the Earth's surface. Fig. 28, often known as Luke Howard's Rain-gauge, from the name of the eminent weather observer who first used it, consists of a copper funnel which is exactly 5 inches in dia-

meter. This funnel dips into a glass receiver (which may be a common wine bottle), and when the rain which is collected is poured into a glass measure such as that shown in Figs. 29 and 30, it can be determined what the rainfall is, because the area of the glass is so much smaller in a definite ratio than the area of the funnel that a fall into the funnel of say ½ an inch is reproduced in the glass measure as a column of water 7 or 8 inches high. There being a risk of glass receivers being broken by accident, or bursting in winter owing to frost, it is usual now-a-days either to replace the glass receiver by a metal vessel, as in Fig. 29, which is Negretti and Zambra's form; or else to use an

FIG. 28.—HOWARD'S RAIN-GAUGE.

open-mouthed glass receiver and stand it and the funnel together in an outer cylindrical receiver, which will gather up the accumulated contents of the glass should any accident happen to it. The little hooked tube shown at E in the detachable top of Negretti and Zambra's gauge is intended to make the metal receiver below to some extent air-tight, so that nothing which has been collected as rain may afterwards be lost by evaporation.

Inasmuch, however, as rain-gauges are usually read daily, this precaution is of no great account in a general way. Indeed it is only necessary to be thought of where a gauge is erected in a place not easily accessible, such as the top of a high tower or hill. In such cases it is not unusual only to examine the gauge once a month; and

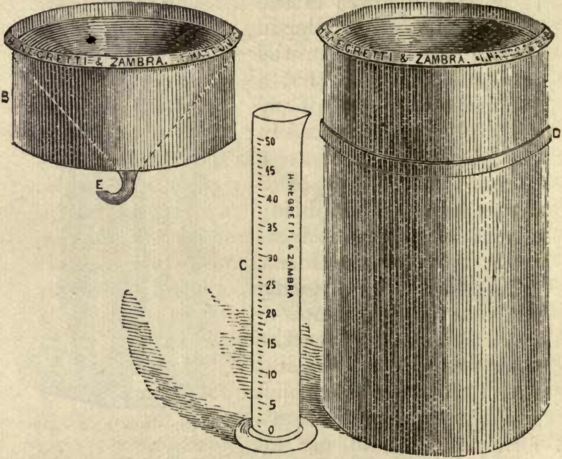

FIG. 29.—NEGRETTI AND ZAMBRA'S RAIN-GAUGE.

where this is the practice it is of course necessary to protect the accumulated rain from loss by evaporation during the intervals between the readings. The rain-gauge shown in Fig. 30 is Casella's form, with a high rim to secure the more correct measurement of snow.

Self-registering rain-gauges have been devised and are in use, but as they would not be likely

to be employed by any who would read these popular pages, I will not occupy space in describing any of them.

Thus far I have spoken of rain-gauges which are supposed to be furnished by a professional instrument maker, but a rain-gauge is really an appliance which an amateur philosopher can readily make for himself. Speaking generally two sizes are chiefly in use: 5 inches in diameter and 8 inches in diameter. Whilst the latter size is that usually employed in large observatories, or by meteorologists who wish to be considered great men, there can be no doubt whatever that a receiver which is 5 inches in diameter is amply large enough for all practical purposes, and is also a convenient size for handling with one hand, for a large gauge will require two hands. It has been proved by repeated experiment that so long as the diameter of a gauge is not less than 3 inches, it will register as accurately as one twice or thrice as large. On the other hand gauges as small as 1 inch or 2 inches in diameter undoubtedly register too little. Nor is

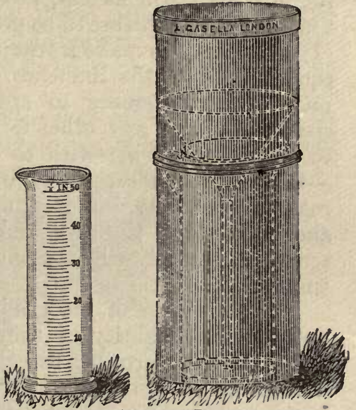

FIG. 30.—CASELLA'S RAIN-GAUGE FOR RAIN AND SNOW.

the shape of the receiving mouth of any great importance; that is, whether it be square or round. Mr. Symons has, however, pointed out that circular gauges are to be preferred because:—(1) It is easier to make a true circle than a true square; and (2) the influence of the rim (or the ratio of circumference to area) is less with a circle than with any other form. With respect to the material wherewith to make a rain-gauge—beyond doubt copper is by far the best as regards durability, but it is not so handy to cut and make up as tin-plate, and accordingly amateurs in general will content themselves with tin-plate.

In making use of the graduated glass to determine the quantity of rain which has been collected, take care that the glass is held exactly upright before noting the position of its contents with respect to the graduations, and treat as the level the point which is mid-way between the two apparent surfaces of the water, some which of course adheres to the side of the glass. If the upper level is treated as the true level the resulting figure will be too great to be accurate; if the bottom of the hollow is taken the resulting figure will be too small.

An ingenious Indian named Jagga Rao, a zemindar of Vizagapatam, once proposed the use of a funnel having a diameter of 4·697 inches, which gives a receiving area of 17·33 inches. Since a fluid ounce of water contains 1·733 cubic inches of water, it follows that every fluid ounce collected by such a gauge represents a rainfall of $\frac{1}{10}$ inch. Glass measures for fluid ounces and

fractions of ounces being readily obtainable in the shops, it is evident that a rain-gauge constructed on Jagga Rao's principles has some claims on the score of simplicity and portability.

Fig. 31 represents a self-registering rain gauge which tells its tale on a dial. This dial is of enamelled glass 6 inches in diameter. It is divided horizontally across its face into 2 inches

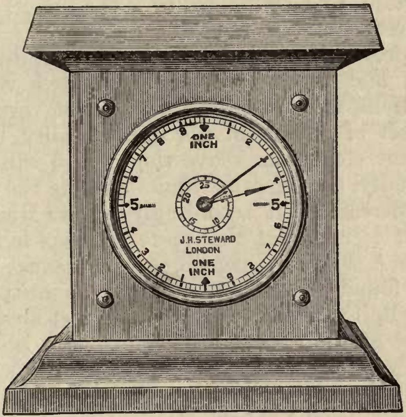

FIG. 31.—SELF-REGISTERING RAIN-GAUGE.

of measurement, the upper half of the dial representing one inch, and the lower half the other inch. Each inch is sub-divided into convenient fractions. A smaller dial registers whole inches up to 25, working somewhat on the principle of a gas meter The instrument is set in motion by the rain falling into the receiver and so into a tumbling bucket which topples over as soon

as it is full, and in doing so releases the mechanism and brings up instantaneously the other bucket to receive another fill of rain: this goes on unceasingly and so the record is continuous; and as the registering goes on instantaneously and unceasingly there is no loss by evaporation to be taken into account.

In carrying on rain-gauge work a point very important to be attended to is the height above the ground of the mouth of the gauge. It has been proved by repeated experiments at different times, and under carefully graduated varying conditions, that the rain which will be registered in a set of gauges in the same locality, but at different elevations above the ground will differ materially, the quantity diminishing as the elevation increases. It accordingly follows from this that it is no proof that more rain has fallen in village A than in village B, merely because gauge A is found to contain a larger quantity than gauge B, if gauge A is erected two feet above the surface of the ground, whilst gauge B is on the tower of B church. If gauges are to be compared together they must be placed at some standard height above the ground, and the standard height now generally recognised is one foot.

The cause of these differences has never been very fully or clearly explained, but it is generally conceded that the influence of the wind is mainly concerned.

CHAPTER IX.

THE WEATHERCOCK.—THE ANEMOMETER.

A READER who has studied even in the most cursory fashion the information given in this volume relating to the wind, will find no difficulty in realising the importance of a careful and attentive consideration of the wind, in connection with the weather. For this purpose a good weathercock is indispensable. Even in regard to so commonplace a thing as a weathercock, experience has more than once shown me that it is expedient here to give some words of caution, and to recommend some acts of precaution. Does it point to the N. when the cock or the arrow (or whatever it be) coincides with the letter N. which is exhibited on high? Does it go round when the wind itself goes round, or does it show that the wind is always, say, S. from day to day and from week to week, though your pipes are frozen and snow lies deep upon the ground, because the weathercock sticks fast for want of grease? These are not ideal difficulties. The student of the weather has from time to time to face all of them. Some people in looking out for the N. point in the erection of their weathercocks are content to take their bearings from a sixpenny compass in hopeless ignorance of the fact that the magnetic N. indicated by the compass differs by many degrees, that is materially, from the true N. point of the Earth. As regards the weathercock itself that

article is poetically a symbol of change and infirmity of purpose, but cases are by no means rare when this doctrine is quite out of place. I know one important church in an important English town, which has a large and handsome wind-vane, which at all seasons of the year indifferently is a fixture for days together, and when it does change does so in a most leisurely fashion after an interval, during which the wind itself will have had time to have gone half round the compass. I mention these matters here in order to warn the reader who is in an observing frame of mind to be quite sure that when he says the wind is S.W. (and is going to commit the statement to writing) he is speaking the truth, and is not relying upon a fraudulent wind indicator, whose N. point is in the E., and which only moves once a month.

When it is a question of studying the wind critically and scientifically, an "anemometer" * must be used. This is an instrument of which there are many kinds, but all may be grouped under two main heads—those which measure the *velocity* of the wind, and those which measure its *pressure*. Of the former kind, that which is in most general use is the "Hemispherical-Cup anemometer," more generally known as "Robinson's," from its inventor, the late Rev. Dr. Robinson, director of the Armagh Observatory. It consists of four hollow hemispheres or cups attached to the ends of two horizontal rods of metal, which cross each other at right angles,

* ἄνεμος, wind, and μέτρον, a measure.

the whole being fastened to a vertical axis, which is suitably secured, and is able to turn freely. When placed to catch the wind the cups revolve, and the arms are of such a length that when a mile of wind, so to speak, has passed over the anemometer, 500 revolutions are registered by the dial, and by a suitable

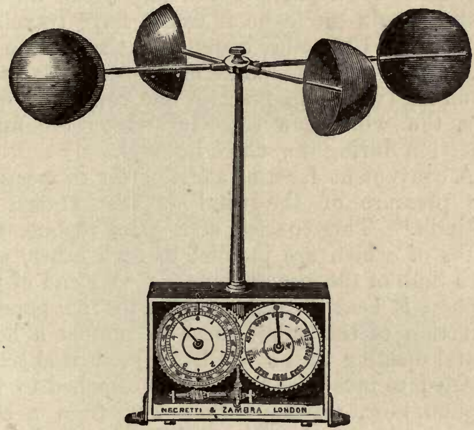

FIG. 32.—ROBINSON'S ANEMOMETER.

combination of wheelwork an aggregate registration of 500 miles, or 1000 miles or more, may be obtained, dependent on the size and completeness of the instrument. The daily record furnished takes the shape of showing how many miles of movement of translation of the air have occurred in 24 hours, and so shows whether

the air has been comparatively stagnant or has undergone much displacement. Perhaps this point will be best understood if I say that a record of, say 100 miles, furnished by a Robinson anemometer, means that if at some given moment observations are commenced, and a balloon is set free at the place, then a record of 100 miles for 3 hours would imply that during that 3 hours the balloon would have travelled to a point 100 miles distant on the surface of the earth from its point of departure, always assuming (which in practice one could not do), that the wind blew steadily and in the same direction during the whole interval.

A convenient form of anemometer to measure the pressure of the wind is that known as "Lind's." This consists of a glass syphon, the limbs of which are parallel to each other, and each limb of the same diameter. One end of the syphon is bent at right angles to the general direction of the tubes so as to present a horizontal opening to the wind. A graduated scale, divided to inches and tenths, is attached to the syphon tube, reading either way from a zero point in the centre of the scale. The instrument is mounted on a vertical spindle, surmounted by a vane, and moves freely in any direction according to the impulse of the wind, always presenting the open end of the tube towards the quarter from which the wind blows. The instrument is prepared for observation by being filled to the zero point with water, and then exposed to the wind. The difference in the level of the water in the two arms gives the force of the wind in

inches and tenths, by adding together the

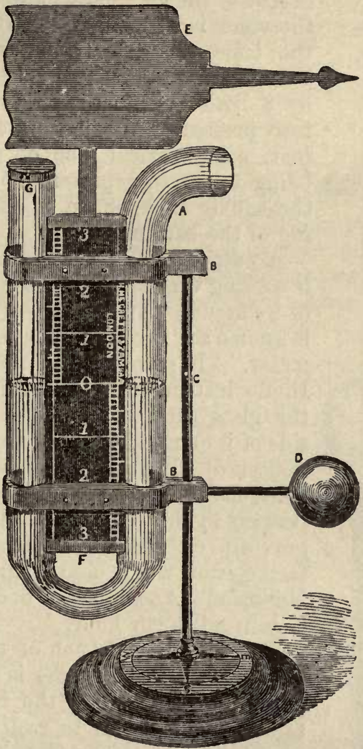

FIG. 33.—LIND'S ANEMOMETER.

amount of the depression in one limb below the zero point, and its elevation in the other,

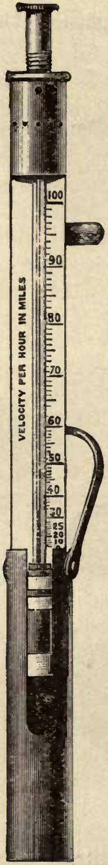

FIG. 34—DINES'S ANEMOMETER.

the *sum of the two amounts* being the height of the column of water which the wind is capable of sustaining at the time the observation is taken. The pressure thus indicated can then, by a little arithmetic, be converted into pressure in pounds on a square foot, each vertical inch of pressure being taken to represent 15 lbs. on the square inch, as we saw in treating of the barometer.

A new form of anemometer which is coming very much into use because of its accuracy and great portability, is known as "Dines's Pressure Anemometer." In principle it is not unlike Lind's instrument just described, but the glass tube is not closed on the side of its outlet, which is away from the wind. It is brought into use by being held upright with the nozzle (shown in the upper part of the engraving on the right hand side) facing the wind, and registers as Robinson's Anemometer does—velocity in miles per hour.

The present variation of the compass in the British Isles is nearly 2 points to the W., so the following table will be useful in assisting the reader to ascertain points when he has no duly adjusted weather-cock or wind-vane to help him, but only a compass.

Compass bearings	N	NNE	NE	ENE	E	ESE	SE	SSE
True bearings	NNW	N	NNE	NE	ENE	E	ESE	SE
Compass bearings	S	SSW	SW	WSW	W	WNW	NW	NNW
True bearings	SSE	S	SSW	SW	WSW	W	WNW	NW

Where an open space, such as a flat lawn, is available, it is very useful, in studying wind and cloud-drift, to have the 4 or 8 chief points of the compass set off from a permanent centre such as a block of stone, by means of other stones marked N.E., &c., at distances say of 20 feet from the centre stone.

Fig. 35 represents an extremely ingenious combination instrument made by Steward, which amateur meteorologists will often find very useful. It is a compass and magnifying glass in one; the compass, of course, for finding one's bearings, and the magnifier for reading barometers, thermometers, or any instruments with graduated scales.

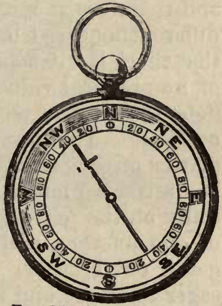

Fig. 35.—The Magnifier Compass.

The lenses are 2 plano-convex pieces of Brazilian quartz worked optically true, and are very strong. The needle is poised between them, and can be used in almost any position, even on horseback.

CHAPTER X.

THE SUNSHINE-RECORDER.

THE Sunshine-Recorder is a modern institution, and can hardly be regarded as a meteorological instrument on quite the same footing as those which I have dealt with up to this point. Of course it goes without saying that plenty of sunshine is essential to the life, health, and prosperity of the world and all its inmates; this is a truism which modern science has completely established, but though men of science can invent and do many things, they cannot make sunshine, and therefore a record of sunshine stands on a different footing from a record of rain: to know that there is a deficiency of sunshine is knowledge of no practical value so far that nothing can be done to turn the recorded information to useful account. The knowledge is therefore only a matter of curiosity. As such, sunshine-recording has attracted much attention of late years, especially on the part of rival watering-places jealous of one another, and a keen competition is now going on between many of those in England eager to assert and to prove instrumentally that their skies are clearer and more sunny than the skies of their competitors in the same neighbourhood.

The sunshine-recorders now in use belong to one or other of two types. Either the record is the result of the burning power of the concentrated solar rays when the Sun is shining, with,

of course, no burning when there is no Sun; or the record is a photographic one. The first sunshine-recorder seems to have been Campbell's, invented in 1853, and based upon the first of the above-named principles; and in various forms (especially in the form known as the Campbell-Stokes Recorder) it has met

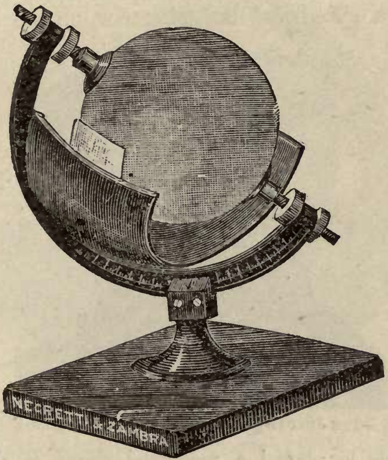

FIG. 36.—THE CAMPBELL SUNSHINE-RECORDER.

with much acceptance. Any instrument based upon the burning power of the Sun no doubt answers its purpose in a way so long as the Sun is shining through a clear sky, but when light clouds or haze are interposed between the Sun and the instrument, the burning power is more or less arrested, and much which would be

called sunshine in a general sense is left unrecorded.

It was to meet this acknowledged defect in the Campbell instrument that Mr J. B. Jordan set to work to invent an instrument, the basis of which should be photography applied as seemed most convenient. The Jordan Recorder takes two forms. In its simplest form it consists of a cylindrical dark chamber, on the inside

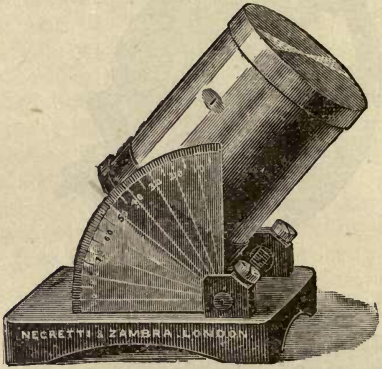

FIG. 37.—THE JORDAN SUNSHINE-RECORDER (Simplest Form).

of which is placed a prepared sheet of photographic paper. The light from the Sun enters through two small apertures in the side of the cylindrical box, one on each side of the meridian, and in the course of the day travels over the paper by reason of the Earth's rotation, and in so doing leaves a distinct trace of chemical action, and thereby registers the duration of the sunshine and the relative degree of its intensity.

The prepared paper is a piece of cyanotype paper, and is divided longitudinally into hours and fractions of an hour, so as to facilitate the record and be available for reference. All that is required to render the record permanent is to immerse the paper in cold water with its face upwards for four minutes, and then to dry

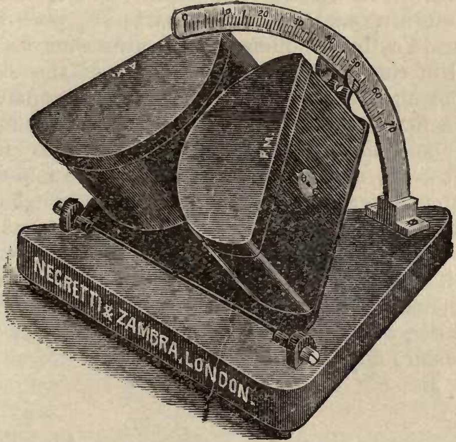

FIG. 38.—THE JORDAN "TWIN-CYLINDER" SUNSHINE-RECORDER.

it between sheets of clean blotting paper. The cylinder is mounted on a simple stand, and requires to be set in the meridian and inclined to point to the Pole according to the latitude of the place where the observation is made.

In the second form of Jordan instrument, known as the "Twin-Cylinder" Recorder,

there are two boxes to contain the prepared paper charts, one for the forenoon record and the other for the afternoon record; and the two records can be afterwards pieced together. The measurement of the trace is thus rendered more easy and more accurate than in the case of the earlier and simpler form. The boxes are semi-cylindrical instead of cylindrical. The fact that the morning and afternoon charts are placed in separate cylinders offers great facilities for changing the charts at convenient times of the day; for instance, the morning record can be removed and a new chart put in place any time after mid-day; and the afternoon record of the previous day can be changed at any time before mid-day without interfering with the forenoon record, which may be in process of accomplishment at the time when the observer visits the instrument. The two half-day charts obtained by the Twin-cylinder recorder can, if desired, be joined together, and so exhibit one continuous trace for the entire day in question.

CHAPTER XI.

MISCELLANEOUS INSTRUMENTS CONNECTED WITH THE WEATHER.

By way of making this Chapter as complete as possible, yet not too long, I will just briefly mention a few other meteorological instruments

which are met with in large observatories, but which are rather outside the general work of an amateur student of the weather.

In 1848 the German chemist Schönbein discovered a new chemical principle, to which, on account of its peculiar smell, he gave the name of "Ozone." A certain amount of mystery may still be said to surround ozone, but it is no doubt a modified form of oxygen gas, and dependent for its abundance mainly on the free development of atmospheric electricity. One thing is quite clear, namely—that it is a powerful disinfectant, and unites readily with foul gases given off from decaying vegetable and animal matter, and by depriving them of their noxious qualities is a great purifier of the air. Hence it comes about that the presence or absence of ozone at any given place and at any given time * has a considerable bearing on the healthiness or unhealthiness of the atmosphere at the moment; and an instrument for testing its presence or absence is not only interesting to the man of science, but is practically useful to the sanitary reformer.

Such an instrument is called an *Ozonometer.*† In its simplest form it is no more than a wire cage (as suggested by the late Sir James Clark), in which can be hung a small test paper in such a way that it is exposed for 12 hours to a free

* It has been well pointed out by Dr. R. J. Mann that there is, in densely-peopled towns, an entire deficiency of ozone in the air; but that it is generally present in full quantity in the air of open country districts, and still more especially in the neighbourhood of the sea.

† Ozone, and *μέτρον*, a measure.

current of air, but is protected from the Sun's rays.

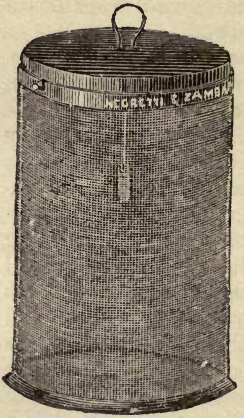

FIG. 39.—THE OZONOMETER, OR OZONE CAGE.

A test paper of the sort used will remain colourless if there be no ozone present; on the other hand, if ozone be present it will become tinged with blue to a greater or less degree, according to the amount of ozone which is available for acting upon it. A scale of different tints is provided, with which the test paper, after it has been removed from the cage and after it has been plunged for one minute into water, is to be compared. The test papers are prepared by boiling together for a few seconds 200 parts of distilled water, 10 of starch, and 1 of iodide of potassium, and plunging into this liquid small strips of bibulous paper. These, when removed and dried, are ready for use. The *rationale* of the effect produced is simply that the ozone if present attacks the potassium and sets free the iodine which produces its characteristic blue colour with the starch. This method of testing air for ozone is not of course a very philosophical one, because discolouration of the test paper may in certain cases be due to the presence of corrosive agents other than ozone.

The *Electrometer** is an instrument which indi-

* Electricity, and *μέτρον*, a measure.

cates rather than measures the electricity present in the air at any given time, for which reason it should rather be called an *Electroscope.* Two

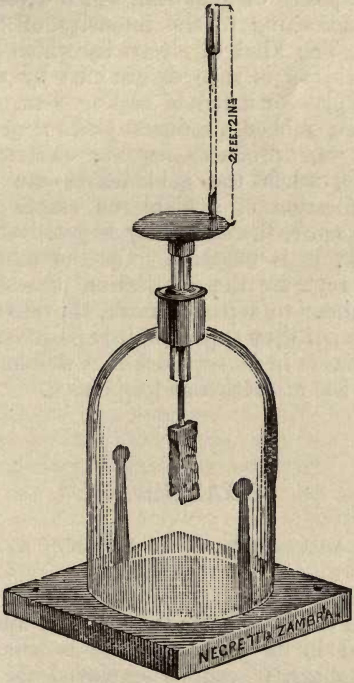

FIG. 40.—THE GOLD LEAF ELECTROSCOPE.

pieces of gold leaf are suspended inside a glass bell jar from the lower extremity of a metallic wire affixed to the under side of a thin brass plate:

from the top of this plate rises a brass rod with a clip for the reception of a lighted cigar fusee. The flame collects the electricity and conducts it to the pieces of gold leaf, which diverge more or less according to the intensity of the electricity. The kind of electricity which has been thus gathered is then determined by means of a rod of glass or a rod of sealing wax. A glass rod when rubbed produces *positive* electricity; sealing wax produces *negative* electricity. If therefore, when the gold leaves are separate the application of a glass rod causes them to separate more, the electricity is positive; if they approach, it is negative. On the other hand, if when separate the application of sealing wax causes them to separate more, the electricity is negative; if they approach, it is positive. These results ensue in consequence of a well-known law of electrical attraction and repulsion.

CHAPTER XII.

THE MEASUREMENT OF HEIGHTS BY THE BAROMETER.

THOUGH the Barometer is commonly and rightly regarded in its popular aspect as essentially a weather-glass, it can be employed for another purpose, and that fact renders it often doubly useful to the tourist and traveller. It can be used to measure the heights of hills and mountains. We have seen that on the Earth's sur-

face, say at the sea level, the weight of a column of mercury which the pressure of the air will support is so much ; say, on an average, 30 inches. If the pressure by the force of natural circumstances becomes greater, then the mercury will rise to, perhaps, 31 inches : if, on the other hand, the pressure is taken off, the mercury will fall to perhaps 27 or 28 inches. But everyone knows that, on ascending a high mountain, the air is found to be much "rarefied," which means that the air pressure will not support 30 inches of mercury, or even 29 or 28, sometimes no more than 24 inches, or 20 inches, or 18 inches, and so on, as we attain a higher elevation up the side of our typical mountain. Hence arose the idea that if the changes which the column of mercury underwent under such circumstances could be reduced to a certain and intelligible rule, the barometer could be used for the direct measurement of altitudes, in substitution for the theodolite and the foot-rule used by the trigonometrical surveyor. And this use of the barometer has now become quite general, since the invention of the aneroid barometer has placed us in the possession of a handy and portable instrument, which can readily be carried from place to place amidst heights difficult of access. The *rationale* of the process is simply what has been stated above: the would-be surveyor takes a barometer reading at his place of departure, and so on other readings in succession as he mounts skywards. But in practice, if great accuracy is desired, numerous subsidiary precautions must be resorted to. A

thermometer must be employed to indicate the temperature of the air (and the temperature of the mercury if a mercurial barometer is used) at each station of two or more; and the barometer and thermometer must be read as nearly as may be simultaneously.

The precautions to be taken include guarding the instruments from the effects of the warmth radiated by the observer's body. The observer should stand to the leeward of the instruments, and thus any warmth which may be radiated from his person will be driven away by the wind, if there is any, or, at anyrate, will be, in a sense, discounted. An approach to within 18 inches will soon cause an elevation of 1° or 2° in the temperature shown by a thermometer, and thus the readings will be falsified both as regards the thermometer and the barometer. It is of great importance to prevent errors arising in this way, for the accuracy of the final results depends very much on these *minutiæ* being duly attended to. Where the observer has any option, and where a fair amount of accuracy is desired, it is expedient to select for the measurement of heights with the barometer a day when the weather is fairly settled, that is, when the barometer is, and seems likely to continue, steady. Several sets of observations should if possible be taken, and a mean value then deduced.

The ordinary aneroid, as sold in the shops, is only graduated to show the customary inches of pressure. When an instrument is intended for the purposes of the traveller or tourist, it

has additional graduations to represent feet from 0 to 5000, or 10,000, or even more. In buying such an instrument think carefully before doing so what countries you are likely to use it in. Beware of graduations for extreme eleva-

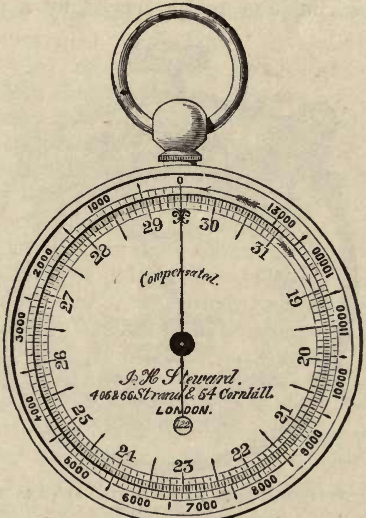

FIG 41.—ANEROID BAROMETER GRADUATED FOR THE MEASUREMENT OF HEIGHTS.

tions which you are never likely to want, because the higher the graduations the more expensive the instrument; and the closer together (and consequently less distinct) are the graduations. For the purposes of the ordinary

tourist in Great Britain or Europe, graduations up to 4000 or 5000 feet are amply sufficient.

Fig. 41 represents an aneroid barometer as commonly made nowadays to serve the double purpose of a barometer and a height measurer. Where, however the measurement of heights is the first purpose to be served by a particular

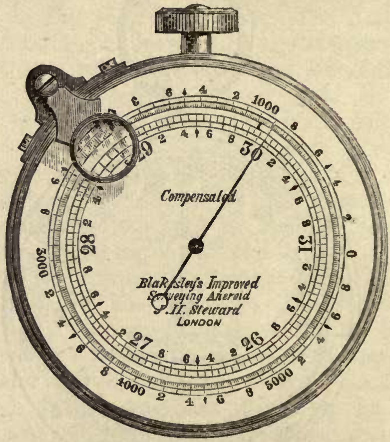

FIG. 42.—ANEROID BAROMETER GRADUATED FOR THE MEASUREMENT OF HEIGHTS.

instrument, and it is desired to have a scale which shall read to as great detail as possible, it is usual to construct the internal mechanism in such a way that equal changes of elevation shall be represented by equal arcs on the dial, and so admit of the use of a vernier for subdividing the main divisions. This means that

equal changes of *pressure* must be represented by *unequal* arcs; and, accordingly, no vernier can be applied to the pressure graduations. The lower the pressure in such an instrument, the wider apart are the graduations: thus, the divisions between 25 and 26 inches, for instance, are wider apart than those between 30 and 31 inches.

The practical importance (occasionally) to travellers of being able to ascertain for themselves their elevation above the sea-level at any given time, was forcibly brought to my notice during the summer of 1896. A lady of my acquaintance suffering from a weak heart went, under medical advice, to the Italian Lakes. She was attracted by casual circumstances to a place called Bormio, near Lake Como, and in two days had an attack of palpitations of the heart. An Italian doctor was consulted, and immediately ordered her off to another locality, saying that Bormio was nearly 5000 feet above the sea, and that she ought never to have gone there (owing to the rarefaction of the air and the cold); that an elevation of 3000 feet must be the extreme height for her to try. Accordingly, she had to pack up in a great hurry, and descend at once to another hotel on the shores of Lake Como. Now had this lady been properly warned, and had she possessed a portable aneroid barometer, with a scale of heights marked upon it, and used it, she would have been saved not only much fatigue, discomfort, and expense, but actual risk to life.

The foregoing may be regarded as a strictly scientific method of determining, by an indirect process, the height of a mountain, but there is

another method, involving the use of less cumbersome and less delicate apparatus, which has come a good deal into use of late years. This is the hypsometrical method.

The boiling point of water is commonly assumed to be 212° at the level of the sea, but at any elevation above this level, the boiling point falls below 212°, and as the elevation successively increases, the boiling point falls lower and lower, in consequence of the progressive diminution of the atmospheric pressure. The practical application of this fact is the basis of the hypsometrical method of determining altitudes.

Figs. 43 and 44 will make the construction sufficiently clear. The thermometer is a specially strong one, graduated and figured on its stem. It is sheltered when in use from extraneous currents of air by a double chamber constructed in telescope fashion, into which it is dropped at the top, and held in its place at any convenient depth by a loose piece of indiarubber at the top of the telescope tube, which clasps it as it were. When the apparatus is started at work by the water being brought to the boil by the spirit lamp underneath, the telescope chamber becomes filled with vapour from the boiling water. The inner chamber and the thermometer tube being thus completely enveloped in vapour, the surplus vapour as it accumulates descends in the outer chamber, and escapes by the spout which serves as an outlet. By this arrangement of the interior of the apparatus, the mercury both in the bulb and in the stem is immersed in pure vapour of water, and so the risk of taking an erroneous

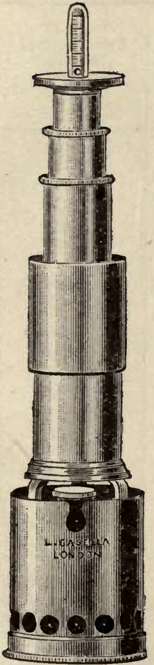

FIG. 43.—EXTERIOR VIEW OF A HYPSOMETRICAL APPARATUS.

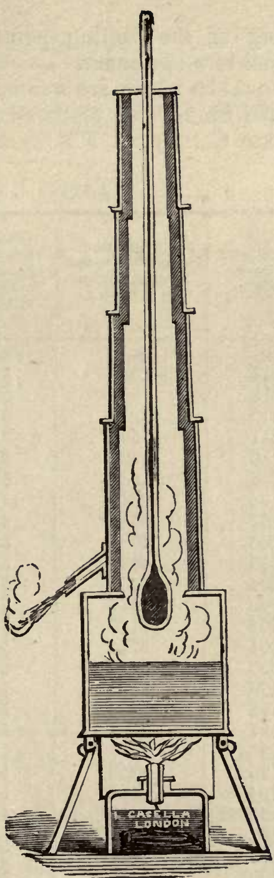

FIG. 44.—SECTIONAL VIEW OF A HYPSOMETRICAL APPARATUS.

reading of the boiling point of the water is reduced to a minimum.

The tables which are wanted are the following, adapted from those prepared many years ago by the late Col. Sykes, F.R.S., and Col. Shortrede.

TABLE I.

Boiling point of pure water.	Approximate height above the level of the sea (or 30·00 in.).	Value of each *tenth* of a degree in feet of altitude.	Corresponding height of barometer.
°	Feet.	Feet.	Inches.
214	−1013	50	31·20
213	507	51	30·60
212	0	51	30·00
211	+ 509	51	29·41
210	1021	51	28·84
209	1534	51	28·27
208	2049	52	27·71
207	2566	52	27·17
206	3085	52	26·63
205	3607	52	26·10
204	4131	53	25·57
203	4657	53	25·06
202	5185	53	24·56
201	5716	53	24·06
200	6250	54	23·57
199	6786	54	23·09
198	7324	54	22·62
197	7864	54	22·16
196	8407	55	21·70
195	8953	55	21·26
194	9502	55	20·82
193	10053	55	20·38
192	10606	56	19·96
191	11661	56	19·54
190	11719	56	19·13

TABLE II.

Mean of the temperature of the air.	Multiplier.	Mean of the temperature of the air.	Multiplier.
°		°	
32	1·001	57	1·055
33	1·003	58	1·057
34	1·005	59	1·060
35	1·007	60	1·062
36	1·010	61	1·064
37	1·012	62	1·066
38	1·014	63	1·068
39	1·016	64	1·071
40	1·018	65	1·073
41	1·020	66	1·075
42	1·023	67	1·077
43	1·025	68	1·080
44	1·027	69	1·082
45	1·029	70	1·084
46	1·031	71	1·086
47	1·033	72	1·089
48	1·036	73	1·091
49	1·038	74	1·093
50	1·040	75	1·096
51	1·042	76	1·098
52	1·044	77	1·100
53	1·046	78	1·102
54	1·049	79	1·105
55	1·051	80	1·107
56	1·053	81	1·109

The temperature of the *vapour* of the boiling water and of the air at the lower and upper stations is ascertained with a thermometer, and then a short calculation, performed with the aid of two simple tables, gives the difference of altitude with a very small amount of trouble.

Casella supplies a compact form of apparatus so portable that it may be carried in the pocket, and by its aid differences of elevation may be determined with considerable nicety.

Table I. gives by inspection the approximate altitude of each station, whence the difference may be obtained by simple subtraction. Table II. furnishes a multiplier for correcting this result to allow for the difference in the temperatures of the surrounding air at the two stations. The multiplier for the mean of these temperatures is to be taken.

The following is an example of the way of using these tables:—

Boiling point at upper station	=	188·3°
	188·0 =	12,843 ft.
Proportional part . .	·3 =	168
		12,675 ft.
Boiling point at lower station	=	206·5°
	206·0 =	3085 ft.
Proportional part . .	·5 =	260
		2825 ft.

Therefore difference of elevation = 12675—2825 = 9850 ft.

Then—

Temperature of air, upper stat.	=	43°
,, ,, lower stat.	=	65
	2	108
Mean of extremes	=	54

Then from Table II. we get 1·049 as the multiplier to be used where 54° is the mean of the two temperatures.

$9850 \times 1·049 = 10,333$ ft. as the corrected difference between the altitude of the two stations.

Mr. Darwin * mentions the following amusing anecdote of an occurrence which happened to his party while crossing the Andes in 1835 due to the fact of the boiling point of water being different at different altitudes. They had attained so great an altitude, and the boiling point was so low, that "our potatoes, after remaining some hours in the boiling water, were nearly as hard as ever. The pot was left on the fire all night, and next morning it was boiled again, but yet the potatoes were not cooked. I found out this by overhearing my two companions discussing the cause; they had come to the simple conclusion that the potatoes were bewitched, or that the pot, which was a new one, did not choose to boil them."

CHAPTER XIII.

WEATHER FACTS AND PREDICTIONS CONNECTED WITH THE BAROMETER.

THIS chapter and the next following chapters will exhibit in a somewhat disconnected and incoherent form a vast variety of statements in

* *Voyage of the Beagle.*

the nature of facts, assertions,* and predictions concerning the weather, drawn from an infinite variety of sources, scientific and non-scientific. It is the result of more than thirty years' reading carried out persistently in the spirit of Captain Cuttle's famous aphorism—"When found make a note of it." Brevity has been deemed essential to the usefulness of the notes for purposes of hasty reference by observers, and this consideration has excluded, except in rare cases, all references to authorities. Least of all do I wish to be regarded as guaranteeing the strict accuracy of every proposition here advanced; everything must be taken *quantum valeat*, and be looked upon as an incentive to the reader to test what he here finds by recourse to the indications of nature, with or without the use of instruments. However, it is hoped that nothing palpably unsound will be met with herein. When a rule has any well recognised exceptions, such exceptions are not treated of unless they have some reference to England.

The barometer is subject to a diurnal variation comprising two maxima and two minima. The maxima occur at 10 A.M. and 10 P.M. within an hour, more or less, and either before or after. The epochs of minima are 4 A.M. and 4 P.M., subject to the same conditions as the conditions just stated with respect to the maxima. The amount of these diurnal variations diminishes

* In connection with this subject an interesting paper on "Weather Fallacies," by Mr J. Inwards, may be consulted. (*Quart. Journ. Roy. Met. Soc.*, vol xxi. p. 49. April 1895.)

from the Equator towards the Poles. [For the reason that they depend on the influence of the Sun's heat on the atmosphere, which is indeed the cause of the diurnal variation at any one place.]

There is also a periodic annual variation in the height of the barometer, but in England it is of inconsiderable amount, and may be disregarded by the general public.

One of the greatest and most rapid recorded changes occurred on September 6, 1865, when the mercurial column fell 1.69 inch in 1 h. 10 m.

In the northern hemisphere the barometer falls with S.E., S., and S.W. winds; with a S.W. wind it ceases to fall, and at W. begins to rise; it rises with a W., N.W., and N. wind, and with a N.E. wind it ceases to rise, and at E. or towards S.E. begins to fall.

When the wind is on the W. side of the compass, changes in the level of the barometric column *accompany* changes of weather, but with the wind on the E. side the indications of the barometer *precede* the changes.

Usually a rising or a high barometer indicates less wind or rain, that is fair weather: a falling or a low barometer more wind, or rain, or both, that is bad weather. But these general rules must be regarded as subject to occasional reservations of a special character, which will be noted in due course.

In temperate climates and in the higher latitudes thereof, the range of the barometer may be taken as amounting generally to something under 3 inches, that is to say, the height of the

column of mercury in a barometer may vary from about 30·8 inch to less than 28·0 inch on extraordinary occasions. The usual range, however, is much less—say from 30·5 inch to 28·7 inch. In the tropics the minimum of depression may be put at about 27·7 inch. It must be understood, of course, that the foregoing figures only apply to places at or near the sea-level.

A fall of half-a-tenth of an inch, or still more, of a whole tenth in one hour, or of $\frac{2}{10}$ths or $\frac{3}{10}$ths in 4 hours, is a sure indication that a storm is approaching.

The barometer falls lower for high winds than for heavy rains. If the fall amounts to 1 inch in 24 hours, a very severe gale may be expected.

If, after remaining steady at about 29·9 inch, the barometer rises and the temperature falls, the air at the same time becoming more dry, as indicated by a hygrometer, then N.W., N., or N.E. wind, or less wind, may be expected.

If when the barometer falls the temperature rises and the air becomes more charged with moisture, that is more damp as indicated by a hygrometer, then wind, rain (or snow), may be expected from the S.E., S., or S.W.

Exceptions to these rules occur when a Northerly wind with wet (rain, snow, or a thunderstorm) is impending, previous to which the barometer often *rises* (but only on account of the *direction* of the coming wind), and thus deceives those who from the fact of the rise of the mercury are led to expect fair weather.

The barometer standing at about say 29·5 inch, a rise foretells either less wind, or a change

of wind towards the N., or less wet. The barometer standing at about say 29 inches, the first rising usually precedes high winds from the N.W., N., or N.E., after which, if it still rises and the temperature falls, improved weather, more dry and very likely sunny, may be looked for. But if the temperature does not fall, probably the wind will "back" (*i.e.* shift against the Sun's course), and more S. or S.W. wind will follow, especially if the rise has been sudden.

The most violent gales, especially from the N. or thereabouts, happen *soon* after the barometer *first* rises from a very low point, or if the wind rises *gradually* at some time afterwards, notwithstanding that the barometer continues to rise.

A simultaneous rise of pressure and temperature—that is, of the barometer and thermometer—is a sure sign of steady fine weather coming on.

Indications of approaching change of weather are shown by the *movement* of the mercury rather than by its absolute height or depression. Nevertheless, a height of more than 30·0 inch is indicative of enduring fine weather with or without moderate breezes, *except* from E. to N. occasionally, when it *may* blow strongly.

It will sometimes happen that a high barometer (say 30·2 inch or thereabouts) may be accompanied by heavy rain with a S.W. wind. This state of things will not last long. [The cause is probably a sudden conflict between the Polar and Equatorial currents, the cold N.E. current condensing the vapour of the warm S.W. current.

After a time the two become so nearly equal in force that a deadlock occurs; while the rotation of the Earth on its axis causes the mass of air to appear to move up from the S.E., and accordingly a breeze unexpectedly springs up from that quarter.]

A rapid rise in the barometer indicates unsettled weather, as also does alternate rising and falling.

A gradual rise, or the mercury steady, accompanied by dryness, foretells fine weather likely to endure for some time.

A rapid and considerable fall is an unmistakable indication of heavy rains and foul weather generally.

If fair weather continues for several days, during which the barometer continuously falls, a prolonged period of foul weather may be expected.

If during a showery period, extending over several days, the barometer steadily rises, the wind being somewhere about S.W., it will eventually happen that the wind will veer to W. and perhaps N.W., and the sky will clear and the temperature fall considerably.

If the barometer goes on falling during a high wind of a South-Westerly character, an increasing storm is probable; if the fall be rapid, the wind will be violent but of short duration; if the fall be slow, the wind will be less violent, but of longer continuance.

A considerable fall of the barometer with wind in the S. is certain to be followed by rain and a rise of temperature.

When the barometer falls considerably without any particular change of weather at a given place, it may generally be inferred that a violent storm is raging somewhere else, at no great distance.

A steady and considerable fall in the barometer during an E. wind denotes a change of wind to the S. as impending, unless a heavy fall of snow or rain follows immediately; in this last-named case there is usually an upper current of clouds coming from the S.

When after a succession of gales and great fluctuations of the barometer, a gale comes on from the S.W. which seems to have no effect, or, at least, no depressing effect, on the mercury, it may be considered that an improvement in the weather is about to set in.

The variations of the barometer are closely associated with changes of wind. Its greatest depression is coincident with gales from about the S.W.; especially in connection with a thaw; its greatest elevation with wind from about the N.E., or with the atmosphere in an absolutely quiescent state, especially during frost.

Although the barometer usually falls with a Southerly wind, and rises with a Northerly wind, yet the contrary sometimes occurs, in which cases the Southerly wind is dry and the weather fine, and the Northerly wind wet and the weather more or less inclement. But sometimes a high barometer (30·2 inch, or so) may be accompanied by heavy rains with a S.W. wind.

When the barometer sinks considerably, high wind with rain or snow may be looked for; the wind will be from the N. if the temperature is,

for the season, low; from the S. if the temperature is, for the season, high.

If whilst it freezes the barometer falls $\frac{2}{10}$ths or $\frac{3}{10}$ths of an inch, a thaw may be expected.

If the weather gets warmer while the barometer is high and the wind N.E., a sudden shift to S. may take place. On the other hand, if while the barometer is low and the wind S.W., the weather becomes colder, sudden squalls from the N.W., perhaps with snow (in winter), may be expected.

Sudden falls of the barometer with a W. wind are sometimes followed by violent storms from the N.W., N., or N.E., and a considerable depression of temperature which in winter means snow.

If a gale sets in from the E. or S.E., and the wind veers by S., the barometer will continue falling until the wind is near a marked change, when a lull *may* occur, after which the gale will soon be renewed, perhaps suddenly and violently, and the veering of the wind towards the N.W., N., or N.E. will be indicated by a rise in the barometer, accompanied by a fall in the thermometer.

The wind usually veers with the Sun, or, as it is sometimes called, "clock-wise," that is in the direction of the hands of a clock (which means right-handed in N. latitudes, and left-handed in S. latitudes); when it does not do this, but goes the other way ("backs"), more wind or bad weather may be expected.

This systematic shifting of the wind will be best understood, perhaps, if exhibited thus:—

Northern Hemisphere.

From S., S.W., W., N.W., N., N.E., E., S.E., to S. again.

Southern Hemisphere.

From S., S.E., E., N.E., N., N.W., W., to S. again.

The barometer sometimes begins to rise before the conclusion of a gale, sometimes even at its commencement, as the equilibrium of the atmosphere begins to be restored, though the pending disturbances may not have wholly run their course.

Though the barometer falls lowest previous to high winds, yet heavy rains often cause a great depression.

If in summer the barometer falls suddenly, a thunderstorm may be expected; and if, when the storm is over, the barometer does not rise, there will be unsettled weather for several days.

Thunder and lightning are frequently preceded by a fall in the barometer; but an exception to this rule occurs when the thunder-clouds come up from the N.E.

Instances of fine weather notwithstanding that the barometer is low may sometimes be noticed, but no reliance must be put upon the continuance of such weather, for wind or rain or both are more or less imminent.

In consulting the barometer with the idea of drawing some conclusions with respect to coming weather, the position of the mercury during

previous days or hours must not be ignored, for an indication at any particular moment *may* be affected by causes operating at a distance and not discernible by the observer whose barometer feels their effect, or as the late Admiral Fitz-Roy put it:—"There may be heavy rain or violent winds beyond the horizon, and the view of an observer, by which his instruments may be affected considerably, though no particular change of weather occurs in his immediate locality."

The longer a change of wind or weather is indicated before it occurs, the longer the indicated weather will last; and, conversely, the shorter the warning the less time will the coming wind or weather continue. In other words:—

> "Long foretold, long last;
> "Short notice, soon past."

Sometimes severe weather from the S., *which will not last long*, may cause no great fall in the mercury because a Northerly wind is impending; and at times the barometer may fall during Northerly winds and fine weather (and therefore apparently against the common rule), because Southerly wind is impending. Changes thus occurring may mislead one unless the possibility of their occurring is kept in mind.

If the barometer at any given place oscillates violently whilst the air there remains calm, it is certain that there are disturbances going on somewhere in a lateral direction, and probably not very far off.

At times in winter a Southerly current may

prevail over a wide area, and the barometer be low and the weather mild. Under such circumstances it may be presumed that severe weather with a high barometer is prevailing somewhere else at no very remote distance. Sooner or later it is probable that the cold and condensed air of this other locality will force its way into the warm and rarefied air of the first-named area, and cause the barometer there to rise rapidly, and wintry weather to set in when nobody is expecting it.

Comparing rainy weather with snowy weather during the course of one revolution of the wind round the compass, the barometer will fall to a lower level during rain than during snow.

If the barometer *rises* very quickly, it is an indication that the Polar and Equatorial currents have met and are in conflict. A severe storm of a cyclonic character is likely to follow, and if the mercury falls as rapidly as it rose the Equatorial current has obtained the mastery, and the storm is near at hand. In such a case the antiquated phrase, "very dry," still seen on barometers of old date, is wholly delusive.

If, in winter, the wind is E.N.E., a rising barometer indicates frost; and should the frost continue, and the barometer go on rising, snow may be looked for.

The barometer is affected by the operation of at least three causes, thus enunciated by Fitz-Roy:—(1.) *The direction of the wind*—a N.E. wind tending to raise it most, a S.W. wind to depress it most; wind from points of the compass between them operating proportionally as

it is nearer one or the other extreme point. N.E. and S.W. may, therefore, be called the wind's *poles.* The range, or difference of height shown, due to change of *direction only* from one of these bearings to the other (supposing strength, or force, and moisture to remain the same) amounts in British latitudes to about *half-an-inch* (as read off).

(2.) The amount taken by itself of vapour, moisture, wet, rain, or snow in the wind or current of air (direction and strength remaining the same) *seems* to cause a change amounting, in an extreme case, to about *half-an-inch.*

(3.) The strength or force *alone* of wind, from any quarter (moisture and direction being unchanged) is preceded and foretold, or accompanied by a fall or a rise, according as the strength will be greater or less, ranging, in an extreme case, to more than 2 inches.

Hence, supposing the three causes to act *together*, in extreme cases, the height would vary from near 31·0 inch to about 27·0 inch, which *has happened*, though rarely (even in the Tropics).

In general, the three causes just mentioned act much less strongly, and much less in accord, so that ordinary variations of weather occur much more frequently than extreme changes.

The height of the mercurial column in the barometer varies according to the elevation of the place of observation above the level of the sea, in addition to the transient variations due to changes in the condition of the atmosphere in the matter of humidity at the place where any given barometer is set up for use. Meteorologists hav-

ing agreed to refer all their barometrical observations to the sea level as the standard level, it is necessary to add to each reading of the barometer a certain correction ($\frac{1}{10}$th inch) for every 100 feet that the barometer read is elevated above the sea, otherwise barometer readings at different stations would not be mutually comparable.

The four highest barometrical pressures ever recorded in London were as follows :—

			Inch.
1778	Dec. 26	2 p.m.	30·918
1825	Jan. 9	9 a.m.	30·922
1882	Jan. 18	10·30 a.m.	30·975
1896	Jan. 9	9 p.m.	30·934

On the last-named day a reading of 31·013 inch was noted ten miles from Chester. This figure was surpassed in Scotland on that self-same day. At Glasgow a reading of 31·091 inches was noted, and at Fort-William one of 31·106, both at about 10 A.M.

Readings higher than this were observed in 1877. At Tomsk, on Dec. 16, a barometer went up to 31·213 inches, whilst two days previously 31·62 inches was reached at Barnaoul.

CHAPTER XIV.

WEATHER FACTS AND PREDICTIONS CONNECTED WITH THE THERMOMETER.

In the northern hemisphere the daily range of the temperature is least in winter, increases considerably in March and April, reaches a maxi-

mum in May or June, continues high during the summer, and diminishes rapidly in October and November, till the winter minimum is again reached.

The daily range is least in wet climates and in the Tropics, and in the Polar regions, and is greatest in dry climates, and in countries in the temperate zones. Hence it is less in Ireland than in Scotland, greater in England than in either of these countries, and greater still on the continent of Europe. [These facts taken together justify the assertion that much as we complain of our English climate, the inhabitants of the British Isles have much to be thankful for to Providence for the comparatively equable climate of the British Isles in contrast with the extremes which occur both in summer and in winter in considerably lower latitudes in central Europe on the one hand, and in the New England States of America on the other. Physically, this mildness is due to the Gulf Stream.]

The daily range in Great Britain in summer is from 12° to 15° in the West and Midland districts, and from 18° to 20° in the South. In the dry climate of Madrid it will sometimes amount to 30°.

The daily range is greater over land than over water. [For there is more radiation (disturbance of temperature) from land than from water.]

The mean temperature of any given day is the mean of 24 observations taken hourly, but observations at the following hours afford a nearly accurate mean for the whole day :—

(1.) Between 8 and 9 A.M. and P.M. in the summer.

(2.) Between 9 and 10 A.M. and P.M. in the winter.

(3.) The mean of $\left\{\begin{array}{c}\text{4 A.M.}\\ \text{10 A.M.}\\ \text{4 A.M.}\\ \text{10 P.M.}\end{array}\right. \left\{\begin{array}{c}\text{6 A.M.}\\ \text{2 P.M.}\\ \text{10 P.M.}\end{array}\right. \left\{\begin{array}{c}\text{7 A.M.}\\ \text{noon.}\\ \text{10 P.M.}\end{array}\right.$

(4.) And generally the mean of 4 observations at equal intervals will give the mean for 24 hours, as also will the mean of the maximum and minimum temperature—without an error, as a rule, of 1°.

When 3 observations are made daily, the best hours are 9 A.M., 3 P.M., and 9 P.M. The observation at 3 P.M. being near the time when the temperature of any given day is at its highest, is of great value in reference to the climate of a locality as well as in reference to other considerations of more strictly scientific interest.

The mean of observations at hours of the same number (or name), A.M. and P.M. do not differ much from the true mean of the day ascertained under circumstances of precision. This is especially true of the hours 9, 10, 3, and 4, A.M. and P.M.

Where the daily range is small (that is to say, in the Tropics and in Temperate regions in winter), the maximum temperature occurs at about 1.30 P.M.; but in Temperate regions in summer not until between 2.30 and 3.30 P.M.

A small daily range coupled with a high dewpoint may indicate the approach of rain.

In winter, and at night in dry, calm, clear

weather, the air is warmer at some height above the ground than it is at the surface. [This explains why fog, which is vapour condensed by chilled air, is so frequently visible in low-lying places, such as meadows at the bottom of a valley, whilst neighbouring eminences are clear of fog.] In such cases the upper rooms of houses in certain situations may be warmer than those nearer the ground—a consideration for invalids.

The houses most protected against severe weather are those on a gentle acclivity a little above the plain or valley from which it rises, and which have a southern aspect with trees on the rising ground in the rear.

It is an undoubted fact that the mean temperature of Great Britain is higher than it was some centuries ago; this is due to the drainage of land generally, and to the extensive reclamation of waste lands which has taken place in so many counties, but especially in the fen districts in and around Cambridgeshire. Glaisher considered that the mean temperature of the year at Greenwich had risen 2° in the 100 years preceding the time when he collated the records at his disposal; and that the increase of temperature is especially marked as regards the months of November, December, and January. [This is a matter of frequent comment on the part of old people in England.]

The winter temperature of Great Britain is so distributed that for invalids a journey towards the S. is of little benefit, unless it is directed at the same time towards the W.; and as the W. temperatures from Wales to Shetland are

uniform, and equal to those of Sussex, it is only the S.W. counties (Dorsetshire, Devonshire, and Cornwall) which are able to hold out inducements to invalids based upon fairly high winter temperatures.

Speaking generally, it may be said that the winter temperature of these counties is 4° in excess of the W. of Scotland and Sussex, and 6° in excess of the E. of Scotland and England.

The S.W. of Ireland may be compared with the corresponding part of England.

The greater the range of temperature, comparing summer with winter, the greater, as a rule, is the death-rate. Hence the greater mortality of England compared with Scotland.

The mean annual temperature diminishes on an average about 1° for every increase of 300 feet in the height above the sea.

When the atmosphere is highly charged with vapour, the escape of heat from the Earth by radiation is obstructed, and the temperature falls but little during the night; but when the quantity of vapour in the atmosphere is small, radiation is less impeded, and the temperature falls rapidly.

It is in virtue of the foregoing rule that the temperature of the air in a large town during calm, clear nights in cold weather is higher than that of the air in rural districts around such a town, because, the smoke hanging over the town, the radiation of the heat created in the town is hindered.

Similarly, in the day-time, the prevalence of vapour obstructs the passage of the solar rays,

and the temperature rises slowly, but in the absence of much vapour the temperature rises rapidly.

The comparative absence of aqueous vapour in mountainous districts facilitates radiation, both solar and terrestrial, and often results in the heat of the Sun striking tourists with scorching effect.

When the air is what we call "sultry," it is saturated with moisture, and evaporation from our bodies proceeds sluggishly. Hence the well-known oppressive sensation often felt in the summer months, especially in July. Under those circumstances there will be very little, if any, difference between the readings of the wet and dry bulb thermometers.

A high temperature with a high dew-point, the wind being S. or S.W., may very likely be followed by a thunderstorm. If the barometer falls much previous to the storm, a general change of weather may be expected.

At any time when the air has been for a while much heated above the usual temperature of the season, a sudden squall, with or without rain, will often come on without much warning.

This is especially true when there is, or recently has been, much electric (or magnetic) disturbance in the atmosphere.

A period of excessive cold is often followed by destructive gales of wind.

A sudden and great change of temperature of the atmosphere either from heat to cold or from cold to heat is generally followed by rain within 24 hours.

In the Northern hemisphere the thermometer rises with E., S.E., and S. winds. With a S.W. wind it ceases to rise, and begins to fall: it falls with W., N.W., and N. winds; and with a N.E. wind it ceases to fall and begins to rise.

The thermometer (shaded from the Sun and freely exposed to the air) when much *higher* between 8 and 9 a.m. than the *average*, indicates Southerly or Westerly wind (Equatorial); but when considerably lower, Northerly (Polar) currents.

The average temperatures of Greenwich in the shade and exposed in air are *nearly the mean temperatures of each twenty-four hours*, taking the year through, around London. Making an allowance for the difference between the mean annual temperature of Greenwich and of any other particular place, the average temperature for the *middle* of each month at such place may be obtained approximately from the following table:—

	°		°
January.............	37	July..................	62
February............	39	August..............	61
March................	41	September..........	57
April.................	46	October.............	50
May..................	53	November...........	43
June.................	59	December...........	39

And proportionally for epochs intermediate between the 15th of each month.

If the thermometer goes up between 9 p.m. and midnight when the sky is cloudless, rain may be expected.

A black frost indicates cold dry weather, especially if it comes on gradually.

If the first frost of autumn occurs late, the winter following will be mild, with variable weather; but if the first frost occurs early a severe winter may be looked for.

During frosty weather, if mist disperses and small detached cirro-cumulus appear in the upper air, a thaw may be expected.

Some of the signs of an impending break-up of a frost are—a watery Sun at sunrise; the Sun setting in bluish clouds and casting reflected rays into them; the stars looking dull and the larger ones only visible; and the Moon's horns looking blunted.

If during a long and severe frost the temperature increases between midnight and sunrise, a thaw may be expected.

If ice cracks much it is a sign that the frost will continue.

One of the surest signs of the breaking-up of a severe frost is the setting in of a N.E. wind if it be accompanied by a greenish or yellowish green sky; and the break-up is all the more certain if the sky becomes gradually overcast, and the wind backs from N.E. to N. and N.W.

A high wind is unfavourable to frost, and as long as it is high it is unlikely that frost will develope, whatever the other dispositions to its doing so may be.

If a frost begins during a S.W. gale, the wind will suddenly change from S.W. to N.W., generally about an hour after sunset, and will

blow very strongly in that direction, accompanied by severe frost, and perhaps much snow. A frost thus arising seldom lasts more than 36 hours. On the morning of the second day the temperature will gradually rise ; before noon the wind will suddenly shift to S.W. ; and then will follow a rapid thaw, very likely accompanied by rain.

CHAPTER XV.

WEATHER FACTS AND PREDICTIONS CONNECTED WITH THE HYGROMETER.

The Moisture of the Atmosphere.

SINCE wind drives away saturated air, and so causes dry air to take its place, evaporation is greater in windy than in calm weather.

A rise in the dew-point between early morning and noon will be followed by rain ; a fall by fine weather.

The evening dew-point generally determines the mean temperature of the night. If, therefore, the dew-point be ascertained, the approach of low temperature or of a frost at night may be indicated beforehand, and may be provided against.

A high evening dew-point indicates, if the dry bulb does not fall much, that the next day will probably be warm ; but a high evening dew-point, with a chilly air and a S.W. wind, is rather a presage of rain.

Damp air is a much better conductor of heat than dry air; consequently it feels colder than dry air of the same temperature, because it conducts away more rapidly the heat from our bodies.

The difference between the dry and wet bulb thermometers will in England sometimes amount to 18°; and will frequently be from 9° to 12°. This sort of thing would occur between April and September. During the winter months the difference will be very much less—say from 4° to 9°.

The temperature of the dew-point is sometimes as much as 30° below the temperature of the air; between April and September the difference is frequently 20°. During the winter months the difference is much smaller, but is often from 6° to 12°. The circumstances favourable to an extreme difference are, the combination of a hot sun with several days of dry E. wind. This condition of things is chiefly met with in the month of April.

When in summer a hot day is not followed by dew, rain may be looked for the next day, especially if there is no wind.

A profuse dew is a very sure sign of fine weather.

The greater the difference between the readings of the wet and dry bulb thermometers, the greater will be the probability of the weather being fine; and *vice versâ.*

Dew and Hoar Frost.

DEW is the aqueous vapour of the air deposited on surfaces cooled by radiation. The quantity

depends on the degree of the cold, and on the radiating and conducting power of the surfaces. Furs, wool, silk, cotton, vegetable substances, &c., being good conductors (relatively), will be much bedewed. Glass, mould, sand, gravel, &c., being bad conductors, will be little bedewed. As Buchan has well pointed out, by a beneficent arrangement, therefore, of the Creator, dew falls most copiously on the objects which most require its refreshing influence.

It is not deposited in cloudy weather, because the clouds obstruct the escape of heat into space by radiation, nor in windy weather, because wind constantly changes the air in contact with the ground, and thus prevents its temperature from falling sufficiently low. When the temperature falls below freezing the dew becomes converted into *hoar frost.*

As dew is not formed during the prevalence of wind, or in the presence of considerable masses of cloud, it is an incidental indication of fine weather.

Hoar frosts on three successive mornings in early spring or in autumn betoken rain, but this rule seems not applicable to April or May.

> "If hoar frost come on mornings twain,
> "The third day surely will have rain."

If a hoar frost disappears without waiting for the Sun, rain is sure to follow.

Heavy dews night after night in August indicate a continuance of settled weather.

When hoar frost is at the first accompanied by

E. wind, the cold may be expected to continue some time. Otherwise, as is well known, hoar frost is rather a sign of changeable weather.

CHAPTER XVI.

CLOUDS MISTS, AND FOGS.

Clouds.

THERE is high authority for saying that a careful study of the clouds, and an attentive consideration of their changes, will generally afford very valuable indications of impending changes in the weather.

This remark seems especially true as applied to the varying tints of the evening sky during or after stormy weather. For instance if a subsisting yellow tint becomes a sickly green, more rainy and stormy weather may be expected; but if it deepens into orange or red, the atmosphere is becoming drier, and fine weather may be looked for.

Small thin clouds, high up in the E. sky before sunrise, and which soon disappear, are sure prognostics in fine weather.

If greenish-tinted masses of composite cloud collect in the S.E., and remain there for several hours, heavy rain and gales of wind may be expected.

A green sky is a certain forerunner of foul weather, which will take the shape of rain, or

snow and frost, according to the season of the year, and according as the wind is Southerly or Northerly in general character.

A red or yellow sky in the morning, at or about sunrise, is one of the most certain forerunners of rain (with perhaps wind) in the course of a few hours.

If at any time clouds are seen to be moving rapidly across the sky, or exhibit in the N.W. a leaden hue, rain may be looked for.

If at sunset the clouds seem disposed to break up and perhaps disappear; and have their edges tinged with red or golden yellow, the weather is likely to become and continue fine and settled.

After fine, clear weather, the first signs in the sky of a coming change are usually light streaks, curls, wisps, or mottled patches of white and distant clouds, which increase in area, and grow together, so that eventually the whole expanse of the sky becomes one unbroken, cloudy mass. If the clouds here referred to seem to be high and distant, the coming change of weather will prove so much the more gradual, but also so much the more certain and serious.

Many small clouds seen in the evening towards the N.W. indicate that rain is gathering, and will come on suddenly.

If the sky after being clear, becomes fretted or spotted over with bunches of clouds, rain will probably soon follow.

"When ye see a cloud rise out of the W., straightway ye say there cometh a shower, and so it is."—*St. Luke* xii. 24.

Mr. Luke Howard, who was the first to study the clouds in detail, proposed nearly a century ago a system of nomenclature for them, which though it has several times been tampered with by other meteorologists has never really been improved.

Howard's nomenclature contemplates the clouds as divided into seven kinds; three being simple and four intermediate or compound. The three simple forms are the *Cirrus*, the *Cumulus*, and the *Stratus*. The intermediate or compound forms derived from the preceding are the *Cirro-cumulus*, *Cirro-stratus*, the *Cumulo-stratus*, and the *Cumulo-cirro-stratus*, the last-named being more commonly spoken of as the *Nimbus*.

CIRRUS is defined by Howard as parallel, flexuous, or diverging fibres extensible in any or all directions.

Cirrus of all clouds has the least density, the greatest elevation, and the greatest variety of extent and direction, or figure. It is the cloud which first appears when a period of fine weather is about to be succeeded by unsettled weather. Slender filaments of cloud begin to stretch in various directions across the sky, and then develope in many directions upwards or downwards or laterally. Sometimes thin lines of cloud arrange themselves parallel to each other, the lines (in the Northern hemisphere) trending from N. to S. or from S.W. to N.E.; sometimes they diverge, curved, from a common centre, and resemble the tail of a horse (hence the common term "mare's tail"); whilst at other times they cross each other in lace-work style.

Cirrus is ordinarily a very certain prognostic of the approach of stormy weather, but small groups of regularly formed cirrus scattered over the sky often accompany settled fair weather, or at any rate fair weather which is not likely to be very soon disturbed.

Horizontal sheets of cirrus which descend quickly and pass into cirro-stratus (presently to be described) indicate unmistakably wet weather.

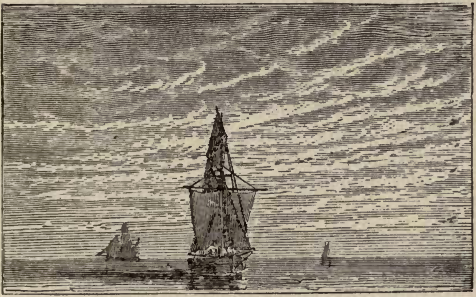

FIG. 45.—CIRRUS CLOUDS.

When streaks of cirrus run quite across the sky in the direction in which a light wind is blowing, the wind will probably blow hard, but in one uniform direction. There will be none of the variable squally weather which usually accompanies storms.

When fine threads of cirrus appear as if swept back at one end by a breeze prevailing in the regions in which they lie, the surface wind, that is the wind on the Earth's surface at the place of

observation, may be expected to veer round to that point if then at some other point. If the direction so foreshadowed be S.W. (whence the storms of Western Europe come), wind and rain will follow, and no matter how settled the weather may seem to be, a storm more or less severe is advancing and will arrive within 30 or 40 hours. When the storm *seems* past and the sky is clear, should a few fine cirrus clouds be seen brushed back at their E. extremities, the storm in all probability is really past and fair weather is setting in. [Because the dry Polar current is asserting its supremacy overhead.] But if the cirrus continues to prevail in all directions, interlaced in the sky, a second storm is approaching.

If cirrus forms during fine weather with a falling barometer, rain is almost certain to follow.

Cirrus seems especially associated with Easterly winds.

A mass of cirrus with fibres pointing upwards is thought to denote rain, but with the fibres downwards dry though possibly windy weather. When cirrus lies from W. to E. a storm is imminent.

If cirrus clouds dissolve and disappear it is an indication of fine weather.

If cirrus clouds spring up to windward and pass into cirro-stratus it is a sign of rain.

If cirrus clouds become lower and denser to leeward, bad weather from the opposite quarter may be expected.

Cirrus of a long, straight, feathery kind, with soft edges and delicate colours at sunrise and sunset is a sign of fine weather.

When during a frost, under a fairly clear sky, long streaks of cirrus are seen with their ends bending towards each other as they recede from the zenith, the streaks of cirrus pointing to the N.E. a thaw and S.W. wind may be expected.

When streamers from cirrus point upwards the clouds are descending, and rain is at hand; when streamers point downwards the clouds are ascending and finer weather may be looked for.

Cirri in detached tufts, popularly called "mare's tails," are a sign of coming wind which often blows from the quarter to which the fibrous tails have previously pointed.

CUMULUS is a form of cloud exhibiting convex or conical heaps, increasing upwards from a horizontal base. They are usually very dense in structure; are formed in the lower regions of the atmosphere, and are carried along in the current nearest to the Earth's surface. The Cumulus has been called the "Day-cloud," being caused by the ascending currents of warm air which rise from the heated ground. The lower surface remains approximately horizontal, while the upper rises into towering heaps which, not unfrequently, swell out into a size far exceeding many mountains. It oftentimes happens that the disposition of these clouds is such, with the upper parts so snowy-white, that the observer might readily fancy that he was gazing not at a cloud at all, but at some snow-clad Swiss mountain.

Cumuli of moderate height and size, with well defined curved outlines and visible only during

the heat of the day, indicate, especially if they come up with the wind, a continuance of fine weather. But when cumulus clouds increase with great rapidity, sink down into the lower parts of the atmosphere, and do not disappear towards evening, rain may be looked for. If loose, fleecy patches of cloud begin to be thrown out, as it were, from their surfaces, especially

FIG. 46.—CUMULUS CLOUDS.

if they move against the wind, the rain is at hand.

If cumuli diminish in size towards evening, they betoken fine weather, but if they increase, foul weather. Large masses of cumulus following rain often precede squalls of hail or rain.

> "A round-topped cloud, with flattened base,
> "Carries rainfall in its face."

If on a fair day in winter a white bank of cumulus springs up in the S., snow may be expected.

If in summer, after the wind has been S. for two or three days, it should become very hot, and large irregular masses of cloud, recalling in some degree an Alpine panorama, spring up, showery, and perhaps thundery, weather is imminent, especially if the barometer is low.

When cumulus clouds become heaped up to

FIG 47 —STRATUS CLOUDS

leeward during a strong wind at sunset, thunder may be expected during the night.

STRATUS is defined by Howard as a widely-extended continuous horizontal sheet of cloud increasing from below upwards. It is properly, and as its name implies, a continuous layer of cloud. It is, besides, the lowest cloud, its lower surface commonly resting on the Earth. It may be called the "Night-cloud," since it generally forms about sunset, grows denser during the

night, and disappears about sunrise. It is caused by the vapours which have risen during the day sinking towards the Earth at eventime as the temperature falls. As the cooling of the air at nightfall begins on the ground and thence proceeds upwards, the stratus takes at first the appearance of a thin mist floating near the surface of the earth. When the Sun has again risen, and has begun to act upon the upper surface of the stratus cloud, it begins to be agitated, and to heave up in different places acquiring the rounded outlines of the cumulus, whilst the lower surface rises in a mass from the ground. As the heat increases, the whole mass continues to ascend, becomes broken up, and eventually disappears. This succession of phases indicates and accompanies settled fine weather.

A stratus cloud at night, followed by a diffused fog the next morning at and after sun-rise, usually betokens a fine day if the barometer is high and steady. If the barometer continues to rise the fog may last all day. If the barometer be low the fog may turn to rain.

CIRRO-CUMULUS is specified by Howard as composed of small well-defined, roundish masses of cloud lying in close proximity, yet separated by intervals of sky which show behind as a blue back-ground. It is formed from cirrus by the fibres breaking as it were and collapsing into small roundish masses, thus destroying the texture, but retaining the arrangement of the cirrus.

This form of cloud is familiar to everyone under the term "Mackerel Sky," and occurs frequently in summer as a concomitant of dry, summery weather; but it is not always to be regarded as indicative of a continuance of such weather. On the contrary, the popular couplet is as true as it is simple and familiar:—

"Mackerel sky, mackerel sky,
"Not long wet, not long dry."

Before thunder, cirro-cumulus clouds often ap-

FIG. 48 —CIRRO-CUMULUS CLOUDS

pear in very dense and compact masses in close contact.

Cirro-cumulus, high above the Earth's surface, commonly appears a few hours or a day or two before thunderstorms. It generally moves with the prevailing surface wind. The more sharp the outline the more unsettled the coming weather. In winter, cirro-cumulus high and

clearly-defined presages bad weather. If the cloud be continuous in long streaks, dense and with rounded knobby outlines, stormy weather will follow within two or three days.

Cirro-cumulus, if soft and delicate in outline, may be followed by continued fine weather; but if dense, abundant, and associated with cirrus, it often betokens electrical disturbance and changes of wind, resulting in summer in thunderstorms and in winter in gales.

CIRRO-STRATUS partakes of the characteristics both of the cirrus and of the stratus. It is defined by Howard as exhibiting horizontal or slightly-inclined masses of cloud attenuated towards a part or the whole of their circumference, bent downwards or undulated, and either separate or in groups. These masses of cloud in their form and relative position sometimes resemble shoals of fishes

In attempting to distinguish cirro-stratus, attention must be paid not so much to the form, which is very variable, but to the structure, which is dense in the middle and thin towards the edges

Cirro-stratus is especially a forerunner of storms Its greater or less abundance and its relative permanence afford some clue to the probable nearness or remoteness of the storm which is impending.

Since it possesses great extent and evenness of texture with little perpendicular depth, it is the cloud in which Mock-suns, Mock-moons, *Coronæ* and solar and lunar Halos present themselves.

Such optical atmospheric phenomena may therefore be regarded as the forerunners of foul weather.

Cirro-stratus occurs with Southerly and Westerly, but rarely with steady Northerly or North-easterly winds, unless a change towards W. or S. is approaching.

FIG 49.—CUMULO-STRATUS CLOUDS.

Long lines of cirro-strati, extending along the horizon and *slightly contracted* in their centre, betoken heavy rain on the following day.

CUMULO-STRATUS is defined by Howard as cirro-stratus blended with cumulus, and either appearing intermixed with the piled-up heaps of the latter, or spreading underneath its base as a horizontal layer. It sometimes appears indistinctly in the intervals of showers.

Cumulo-stratus immediately precedes the fall of rain or snow, according to the season of the year.

The gathering together of ash-coloured masses of cumulo-stratus and cirro-stratus over the sea, extending in a line from S.E. to S.W., is often a forerunner of rain, and probably of wind on the second day.

When large masses of cumulo-strati clouds

FIG. 50.—NIMBUS CLOUDS.

collect simultaneously in the N.E. and S.W. with the wind E, then cold rain or snow may be expected soon, the wind ultimately backing towards the N.

CUMULO-CIRRO STRATUS, more commonly called NIMBUS. This is the Rain-cloud, that is, the cloud or system of clouds from which rain descends. This often has its origin in the cumulo-stratus which increases till it overspreads the sky and

becomes black or bluish-black in colour. This colour soon changing to gray, the nimbus proper is formed and rain begins to fall.

The name "cumulo-cirro-stratus" suggests more accurately the manner in which the rain-cloud is formed. At a considerable height a sheet of cirro-stratus is spread out, under which cumuli drift from the windward; these rapidly increasing, unite at all points, and eventually form one continuous gray mass from which the rain falls. Eventually the lower gray mass begins to break up, and this indicates that the rain will soon cease.

When a rain-cloud is seen approaching, cirri appear to shoot out from the top in all directions; and it has been noticed that as the cirri are more numerous, so the rain-fall will be more copious.

The remaining paragraphs respecting clouds are of a miscellaneous character and cannot well be classified.

When clouds are seen drifting about aloft, the air on the ground being still or nearly so, wind is approaching; and the clouds indicate the direction from which it will come.

Clouds drifting about at sunset, from whatever quarter betoken rough weather.

Dusky clouds, or clouds of the hue of tarnished silver, are a sign of hail. If traces of blue are visible, the hail will be small; if traces of yellow, it will be large.

It was the opinion of Sir J. Herschel that

"anvil-shaped" clouds are likely to be speedily followed by a gale of wind.

If small clouds increase, expect rain; but if large clouds decrease, expect fine weather.

Soft, filmy clouds indicate fine weather, with light breezes; but clouds with hard sharp edges indicate wind.

A dark, gloomy blue sky is an indication of wind; but light, bright blue sky betokens fine weather.

And, generally, it may be said that light delicate, quiet tints or colours, with clouds of soft, ill-defined outline, indicate and accompany fine weather; whilst gaudy or unusual hues and clouds of hard outline betoken rain and wind.

As an alternative way of submitting this point, it may be said that the softer and more silky the clouds look, the less the amount of wind (but perhaps more rain) which may be expected; on the other hand, the harder, more tufted, and more ragged the clouds are, the stronger will be the wind when it comes.

Fragments of clouds (often spoken of as "scud") driving across heavy masses of cloud presage wind and rain; but if scud alone is flitting about, the indication may be merely of wind.

Clouds up aloft at great elevations crossing the sky in a direction different from that indicated on the surface of the earth as the direction of the wind foretell a change of wind towards their direction.

Clouds in the E. obscuring the Sun indicate fair weather.

Dark clouds in the W. at sunrise portend rain during the day.

A squall cloud which one can see through or under is not likely to bring, or be accompanied by, so much wind as a dark continuous mass of cloud extending to the horizon and below.

A bank of clouds in the W., especially if it has formed gradually, and has evidently become dense, means rain.

A long stripe of cloud, in shape it may be to a fish, indicates foul weather if it trends E. and W., but fine weather if N. and S.

While any of the clouds, except the nimbus, retain their primitive forms, no rain can take place; but by observing the changes and transitions of cloud-form weather may be predicted. It was Luke Howard who framed this aphorism in these terms.

When clouds break before the wind, leaving a clear sky, fine weather will follow.

If in the morning clouds are moving about, impelled by two currents, and those in the upper current come from the N.W., a fine day will ensue.

A sky covered with clouds need not cause apprehension if the clouds are high and of no great density, and the air is still, the barometer being at the same time high. Rain falling under such circumstances is generally light and of not long continuance.

The apparent permanency and stationary aspect of a cloud is often an optical deception arising from the solution of vapour on one side of a

given point while it is precipitated on the other.

Clouds floating at different heights indicate the existence of several currents of air, and generally the upper one will eventually prevail. If this is N.E. fine weather may be expected; if S.W., rain.

A very clear sky without clouds, especially in the morning or early forenoon, is not to be trusted unless the barometer is high.

A dark gloomy indigo blue sky betokens wind, but a light azure blue sky betokens fine weather.

The most cloudy countries are those where the wind is most variable—*e.g.* the British Isles; the least cloudy countries are those where the wind is least variable—*e.g.* Egypt.

If a cloudy day clears up at night, rain may nevertheless follow. [The clouds are dissipated by sinking into a warm lower stratum of air, but the moisture remains, and it is only a question of time when it shall be precipitated as rain.]

Mists.

It has already been stated that mists and clouds are closely co-related. Mists often appear sooner on parts of hills covered with trees than elsewhere. This happens especially when the mist begins to form after mid-day. [Because then the temperature of the trees is lower than that of the grassy slopes.] Similarly, mists often linger longest over forests. [Probably this is on

account of the comparative cold of forest air arising from the large evaporating surface presented by the leaves of the constituent trees which, be it remembered, are all the while enshrouded in mist.]

It seems a universal rule—local proverbial sayings in all parts of the country embody it—that misty clouds forming and hanging about, or capping heights, whether mountains or hills, indicate that wind and rain are imminent. On the other hand, if such clouds rise, and still more, if they disperse, fine weather is approaching.

A sudden haze coming over the sky is due to the mixing of two currents of unequal temperatures. The result may be rain or a rise of temperature; or a general change of weather before very long.

A morning mist which breaks up into soft cumuli clouds betokens a fine day. Frequent mists foretell rain, and a gloomy mist, especially, is an indication of rain. [The gloominess is owing to the presence of black clouds overhead which will supply the rain.]

Mists in autumn are often followed by wet; but in spring or summer this is seldom the case.

If in summer towards dusk a mist is seen to rise from a stream, or meadow, the next day will be warm.

If in the evening in spring or autumn, vapour rises from a river, a frost may be considered as impending.

If the observer with his back to the Sun finds the landscape facing him is clear, it is a sign of fine weather; but if he faces the Sun and the

landscape is clear, showery unsettled weather may be expected.

Mists are usually coincident with barometrical extremes—either very high or very low pressure. [A high barometer testifies to a period of calm, during which vapour has been able to accumulate; a low barometer testifies to rarefaction of the air, which is consequently incapable of sustaining much vapour in suspension.]

Fogs.

Fogs do not occur in windy weather. They are driven away when a breeze springs up, unless dissipated by other causes.

When fog descends fair weather follows, but when it ascends rain follows.

A damp fog or mist accompanied by wind is a precursor of rain.

Light fog passing under the Sun from S. to N. in the morning indicates rain in two days or less.

If in winter a cold and a warm current meet and the latter (of course a Southerly one) is overcome by the former (a Northerly one), the barometer will rise considerably at places near the line of contact, and a dense fog will appear. This fog often disappears suddenly and may then reappear, and perhaps such alternations may occur several times; the alternate predominance of the two antagonistic currents is indicated by this. If great cold ensue it will be a proof that the Northerly, which is of course the Polar current, has eventually gained the mastery.

In summer a fog from the N. presages rain, but from the S.E. warm weather.

Fogs in January presage a wet spring. Fogs in August a severe winter and much snow.

CHAPTER XVII.

RAIN, THUNDER, LIGHTNING, HAIL, SNOW, SLEET.

Rain.

MORE rain falls on land than at sea, especially in hilly or mountainous countries, and so the general temperature of the superincumbent air will be raised by the latent heat thus given out. [For this reason the Northern Hemisphere because it comprises more land than the Southern Hemisphere, is warmer than the Southern Hemisphere.]

The drainage of agricultural land has been proved to have raised the mean annual temperature, and therefore such operations tend to the increase of crops. [But to the detriment of the wells.]

Places having a considerable rainfall are characterised by a low pressure as indicated by the barometer.

More showers of rain happen between 2.0 and 3.0 p.m. than during any other hour. Rain is scarce between midnight and 1.0 a.m. In London, if in the forenoon there is a prospect of rain then, from 1.30 to 2.0 p.m. is often the time when either the rain will come on, or the prospect of it pass away for the rest of the day.

In weather which is showery rather than steadily wet, when between the intervals of sunshine a cloud appears in the W., passes overhead of the spectator, and as it passes pours down a considerable quantity of rain, if the barometer be watched from the time of the cloud's appearance in the W. till it is lost in the E., it will be observed to fall a little, and then to recover its original level. Such a fall is quite a local one.

Usually there is fair weather before a considerable spell of rain.

A long and serious drought is often followed by a long spell of wet and unsettled weather.

If after rain has seemed imminent several days of fine weather occur, it is certain that the condition of the air has undergone change; that the aqueous vapour has been driven off before it has had time to condense. A change of wind will accompany such a general change.

A small cloudless area in the N.E. horizon is a certain forerunner of a clearing up and more settled weather.

If the sky becomes darker without much rain, and the clouds seem to shake down into two distinct layers, gusts of wind may be expected.

If much rain from the S. is followed by fine weather for a week, the wind remaining S., a prolonged absence of rain may be expected.

If rain comes from the S., with a high wind for two or three hours, and the wind falls, but the rain continues, it may continue for 12 hours or more, and until a shift of the wind through W. to or towards N.W. clears and cools the air.

Small drizzling rain, especially in the morning, is a sign of wind to come.

Rain usually comes from the W. or thereabouts. A clear sunset is therefore a proof that no rain is imminent from that quarter, nor probably is very near from any quarter.

In winter, rain with a W. wind and a rising barometer, turns to snow.

It very often happens that wind ceases when rain comes on. It is this fact which is conveyed by the common expression, "It seems blowing up for rain."

Sudden rains never last long; but when the air grows thick by slow degrees, and Sun, Moon and stars become gradually more dim, several hours of rain may be expected.

Many attempts have been made at various times to associate the fall of rain with particular hours of the day. Some suggestions as to this will now be given, but it cannot be said that much certainty exists on the subject, except perhaps in the case of the following saying:—

> "Rain before seven,
> "Fine before eleven."

Various other suggestions on this subject will next follow.

If rain begins to fall an hour or two before sunrise, it will cease before noon, and continue fine for the rest of the day; but if the rain begins an hour after sunrise, it is likely to continue raining all day, except a rainbow be seen before it rains.

Rain at midnight, with a S. wind. will generally last 12 hours or more.

Another batch of rain rules which must be taken for what they are worth runs as follow :— If rain commences before day-light, it will hold up before 8.0 a.m. ; if it begins about noon it will continue through the afternoon; if it commences after 9.0 p.m., rain will fall the next day; if it clears off in the night, it will rain the next day; if the wind is from the N.W. the storm will be brief; if from the N.E. it will be severe; if from the N.W. it will be cold; if from the S.W. warm. If it ceases after midnight, the next day will be rainy; if it ceases before midnight the next day will be clear. Rain beginning about 5.0 p.m. will last through the night.

The heaviest rains begin with an Easterly wind, which gradually veers round to S. and W., or a little N.W., when the rain usually ceases.

Rain may be expected when the sky assumes an almost colourless appearance in the direction of the wind, especially if lines of dark or muddy cirro-strati lie above and about the horizon.

A heavy shower after the commencement of a gale of wind indicates that the wind will not be of long duration. This same idea is conveyed by the maxim that if the wind increases in force during rain fair weather may be expected soon.

It is a very sure sign of approaching rain if the sky assumes an almost colourless appearance in the direction of the wind, especially if lines of dark or muddy cirro-strati lie above and about the horizon, and the milky hue of the sky

gradually becomes much denser or muddy, as it were.

More rain falls in summer than in winter, and most in autumn.

More rain falls by night than by day. [Because the cold at night condenses and cools the air, and thus diminishes its capacity for holding moisture in suspension.]

The amount of moisture in the atmosphere is greatest near the Equator, and diminishes towards the Poles; hence it follows that the rainfall in tropical regions is far heavier than it is in temperate regions.

The zone of greatest moisture follows the Sun across the Equator to the N., or to the S., as the Sun's declination changes.

The regions of greatest heat are also the regions of greatest rainfall.

More rain falls in the Northern hemisphere than in the Southern hemisphere.

As to the rainfall in Great Britain, it may be said that more rain falls on the Western than on the Eastern coasts, in the ratio of 2, 3, or even 4 to 1, dependant upon the physical configuration of the land, the pressure or absence of trees, and other special local circumstances of kindred character. Localities having a small annual fall receive most of their rain in the summer; but at wet stations winter is the season of most rain. In all except mountainous districts the quantity of rain which falls increases about $2\frac{1}{2}$ per cent. for every increase of 100 feet in elevation above the sea level. The wettest place in the British Isles is the Stye-head Pass, one

mile S. of Seathwaite in Borrowdale, in Cumberland, where the average annual fall is 165 inches. The dryest district in England is that around Lincoln, where the average annual fall is only 20 inches. Comparing the E. with the W. of England, the average falls, over the whole area, neglecting special extremes, are 25 inches in the former, and 40 inches in the latter.

Contrast with these figures the following instances of tremendous rainfall which have been recorded:—Loch Awe, Scotland, 7 inches in 30 hours; Joyeuse, France, 31 inches in 22 hours; Gibraltar, 33 inches in 26 hours; hills above Bombay, 24 inches in one night; the Khasia Hills, 30 inches on each of 5 successive days. On these hills the *annual* rainfall is said to be 600 inches.

Speaking generally, it may be said that the fall in the driest year will be one-third below the average; whilst that in the wettest year will be one-third beyond. Hence, it follows that the fall in the wettest year will be double that in the driest year, and, therefore, an excess or defect of say 20 per cent. entitles us to call any particular year a "wet" or a "dry" one, as the case may be.

The wettest months at most lowland stations are July, August, and October; but in mountainous districts December, January, and February are the wettest months.

The rainfall is more evenly distributed through the year at W. coast stations than it is at E. coast or dry stations. This fact may be put in another form:—The heaviest of heavy falls, say

in 24 hours at a wet station, will not amount to 6 per cent. of the annual total; whilst at a dry station a heavy fall may amount to 10, 12, or 14 per cent. of the whole annual quantity. The question whether the rainfall of England is increasing, diminishing, or remaining stationary must be answered by saying that observations extending over about a century and a half indicate, if anything, a slight increase.

The average rainfall for all England may be taken at 31 inches; for near London it is appreciably less, say 25 inches.

In the British Isles rain falls on an average on 183 days during the year. On 90 of those days the fall will be less than $\frac{1}{10}$th, yielding about 4 inches; and on 15 days it will exceed $\frac{1}{2}$ inch, yielding about 11 inches.

It will happen at least once during a term of years at some time or other that there will be a specially heavy fall, say 3 to 4 inches; and it may probably be said that no part of Great Britain is free from the chances of such a visitation.

As long as the diameter of the rain-gauge exceeds 3 inches, it seems to make hardly any difference in the amount of the rain recorded whether the diameter of the gauge be 4 inches or 24 inches.

A rainfall of $\frac{1}{10}$th inch represents about 10 tons, or 2262 gallons to the acre; a rainfall of 1 inch, therefore, represents about 100 tons, or 22,600 gallons to the acre.

Rain which reaches Great Britain may be said to do so in two distinct types of fall:—

(1) The oft-recurring rains of winter which accompany Atlantic depressions of the barometer as they sweep one after another over the British Isles, and which give the maximum monthly falls to our Western and Northern districts between November and January; (2) those heavy, often local, and often comparatively brief, falls which accompany thunderstorms, and make themselves more distinctly felt over the low-lying and comparatively level parts of England, such as London and its neighbourhood, and the Eastern half of England generally. It is owing to the rainfalls of this second type that we have two *maxima* in the mean monthly rainfall of London, one in the summer (month of July), the other connected with the approach of winter, and which seems statistically to be associated with the month of October.

It is a thoroughly well-authenticated fact that after a succession of bright days, when the air is calm and highly charged with moisture, any violent concussion will force a part of it into a higher colder region, where it will be rapidly condensed into rain. Hence many great battles begun in fine settled weather have been finished amidst a downpour of rain—*e.g.*, Valenciennes, July 1793; Dresden, August 1813; Waterloo, June 1815; Algiers, August 1816.

Volcanic eruptions also seem to have the same effect of provoking rain.

What constitutes a "drought?" This is a question not easily answered. A week without any rain is certainly in one sense a period of "drought," but the word is not properly used if employed

in such a connection. Hardly less ridiculous is it to call 14 days without any rain a drought, as Mr. G. J. Symons has suggested. Nothing less than a month of 30 days should be regarded as a condition of things to which the term "drought" should be applied; and if $\frac{1}{100}$th of an inch should then fall even on more than one day, there would still be no effective break in the drought then going on; and if two months elapsed before a tenth fell, then, and not till then, should the drought be deemed at an end. In such a case it should be said that the drought terminated, having lasted two months, the two or three intervening days of $\frac{1}{100}$th of an inch each really going for nought.

Thunder.

Thunderstorms almost always occur when the weather is relatively warm for the season.

It is a suggestion more than three centuries old that thunder in the morning signifies wind, about mid-day rain, and in the evening tempestous weather with much rain.

Thunderstorms are most frequent in the Tropics, and diminish in frequency towards the Poles. They are more frequent in summer than in winter; in mountainous countries than in plains; during the day than during the night; after mid-day than before mid-day.

Just prior to the bursting of the storm, the air is exceptionally warm and stifling; and this characteristic is especially noticeable in winter and at night.

After the storm is past, a great fall occurs in the thermometer.

Sometimes heavy thunderstorms occur overhead in the higher regions of the atmosphere without any material fall of the barometer; in this case the customary fall of the general temperature on the earth's surface will not take place.

During the continuance of a thunderstorm, rain falls more heavily after each clap of thunder.

Thunderstorms coming up with an E. wind while the barometer is falling do not cool the air; it remains sultry, and another thunderstorm may be looked for as at least likely to occur in the neighbourhood. Not till the wind gets round towards the W. and the barometer begins to rise will the temperature of the air fall.

If several thunderstorms come on in succession from the W., each storm usually has a more Northerly drift than the one which preceded it.

Thunderstorms in spring lie at a low level, and do not last long; they are usually followed by a period of cool weather.

Thunder and lightning late in autumn or early in winter indicate a spell of warm weather.

A summer thunderstorm which does not much depress the barometer will be of a local character, and not serious.

The general direction of a thunderstorm is either from E. to W., or from N. to S.; not often is its direction oblique to the four cardinal points.

Thunder occurs commonly when the wind is S., more or less; very rarely when it is N.

In summer or early autumn, if after the wind has been S. for two or three days, the air should become very sultry, and numerous clouds with white summits and blackish bases present themselves, thunder and rain are imminent; if two independent masses of such cloud are seen approaching on different sides, a storm is very near.

Much thunder in winter bodes ill for next summer's harvest.

The more thunder in May, the less in August and September.

Thunderstorms at the beginning of August will probably be followed by frequent thunderstorms during the month.

The thunderstorms of the season will come more or less from the same quarter as the first one.

> "Thunder and lightning in the summer show
> "The point from which the freshening breeze will blow."

A thunderstorm often affects milk and puddings into the composition of which milk has largely entered. [This is due to the fact that the increased electricity in the air oxydises the ammonia in the air, forming nitric acid, and it is this which injures the milk.]

Lightning.

There is more lightning in summer and autumn than in winter or spring.

That form of lightning known as "silent" or "sheet" lightning (unattended by thunder) is often a prognostic of unsettled weather approach-

ing; when it is not such, it is at least an indication that stormy weather is occurring within any distance b-tw-en 20 and 200 miles.

Lightning in the N. is often said to betoken rain, but the evidence as to this is scanty.

Sheet lightning in the early morning during winter, especially on the Western coasts of England, is a sign of bad weather.

Hail.

Hailstorms are usually very local in their character; they seldom occur during night or in winter, but most frequently in summer, and during the hottest part of the day.

A hailstorm by day will often be followed by a frost at night in the late autumn, the winter, or the early spring.

Hail squalls instead of rain squalls in winter are a sign of further bad weather being in prospect.

Snow.

Snowflakes vary in size from $\frac{1}{14}$th inch to 1 inch. They are largest when the temperature is near 32°, and smallest when the temperature is very low. The crystals of the same fall of snow are generally similar to one another, but one set of crystals will differ a good deal from another, though, however much they may differ, they will be found to affect a hexagonal form.

In winter during a frost, if snow begins to fall, the temperature of the air will generally rise to 32° or thereabouts, and will continue there whilst

the snow falls. If the sky then clears, the cold may be expected to continue, unless the wind shows signs of veering to the E. or S.E.

"When the snow falls dry
"It means to lie;
"But flakes light and soft
"Bring rain oft."

If the snowflakes are large in size, or if beginning small they increase in size, there will soon be a thaw, especially if the wind is Southerly.

Usually snow with an E. wind and a falling barometer turns to rain, the wind becoming more Southerly.

If after severe cold it begins to snow, and the wind veers from E. to S.E., and the barometer falls, and the cold becomes less intense, still the thermometer may remain below 32°. In such a case, when the wind reaches the S. the snow does *not* turn to rain; and if the Southerly current is displaced, the snow will continue almost or quite uninterruptedly.

Snow will often fall without the barometer going down and giving any warning that the snow is coming.

Snow with a W. wind brings more cold, though perhaps after an interval. [Because snow is more usual with a W. than with an E. wind, and a W. wind is apt to work round and become a N. wind, whilst an E. wind commonly works round towards the warmer side of the compass.]

Snow can never fall when the temperature is very low. What sometimes appear to be snow-

flakes with a very low thermometer are rather *spiculæ* of ice dropped from a stratum of clouds belonging to a warmer current which happens to be overhead at a great distance. These *spiculæ* passing in their fall through very dry air cannot increase in size, and therefore cannot assume the form of flakes, because flakes are aggregations of frozen material.

A deficiency of winter snow is bad for the crops of the following summer.

Sleet.

Sleet appears to be formed as the result of snowflakes falling through a stratum of moist air at a temperature of 32° or more. Sleet falls chiefly in winter and spring, and is very rarely an accompaniment of a storm.

CHAPTER XVIII.

WINDS.

TWO principal currents blow over the Northern Hemisphere of the Earth; the Equatorial current Northwards *to* the Pole, and the Polar Southwards *from* the Pole.

The Equatorial current is warm; the Polar current cold. [Because winds acquire to some extent the temperature of the regions over which they have passed.]

Moist winds blowing from the open sea are

coincident with a mild temperature in winter and a cool temperature in summer. [Because air charged with vapour obstructs both solar and terrestrial radiation.]

Similarly, dry winds from a continent may be said to bring cold in winter and heat in summer.

The Equatorial current becomes a more moist wind as it travels N. [Because it loses heat, and therefore approaches nearer the point of saturation, or, as some put it, because it is blowing from regions of much moisture to regions of less moisture.]

The Polar current becomes a more dry wind as it travels S. [Because it gains heat, and therefore recedes from the point of saturation; or, as some put it, because it is blowing from regions deficient in moisture to regions where moisture is abundant.]

Hence in England the S.W.* wind is particularly moist. [Because it is both an Oceanic and an Equatorial wind]; and the N.E.* wind is particularly dry. [Because it is both a Polar and a Continental current.]

Western borders of continents in the N. Temperate Zone, where the prevailing wind is S.W., enj y a comparatively high temperature in winter. [Because they are protected from extreme cold by the warmth brought by the said wind from the Ocean in their proximity; and they are

* Why currents N. and S. at their origin become N.E. and S.W. by the time they arrive in Britain is a question of physical geography. The fact is due to the Earth's rotation.

farther protected by their moist atmosphere and clouded skies.]

But in the interior of the Continent it is otherwise. [Because the S.W. wind, getting colder and drier as it advances, the soil is exposed to the full effects of radiation during the long winter nights, and, as the ground is more or less covered with snow, little heat can ascend from the soil below to counteract the cold on the surface, and so the temperature falls considerably.]

It is much hotter in the interior of continents in summer than at the Western borders. [Because the land, being warmer than the Ocean at this season, the wind becomes warmer as it traverses the land, and the superincumbent air being drier, the rays of the Sun act with an intensity which is always more or less excessive.]

Wind blows from regions where the barometer is high to where it is low, and with a force proportioned to the difference of the pressures * ; and places *between* very high and very low pressures feel most severely the violence of the resulting storm, and *not* those where the pressure is absolutely the lowest.

If the wind being N. passes to N.E., we get clear weather; the air is dry, the barometer high, and in winter a considerable development of cold occurs. If the wind continues to veer, and reaches the E., the barometer will fall, and the sky become more or less overcast. Snow,

* It is in connection with this that the new terminology (*e.g.* "gradients," &c.), which has been already referred to, has come into use of late years.

and afterwards S. wind, may then be expected. If the barometer should fall rapidly, the snow will turn to rain, and a thaw set in if the wind continues to veer through S.E., and S., to S.W.

If a N.E. wind be accompanied in winter by a clear sky, with haze near the horizon, and the barometer be high and rising, or at least stationary, and the wind does not increase in force, but tends to change in the direction of E. and S.E., the weather will probably continue settled for some time, at any rate, as long as the wind keeps to the S.E. quarter.

Of S.E. wind there are two distinct kinds; one with a low barometer, accompanied by warmth and moisture, ending in rainy or stormy weather; the other with a high barometer, rising or stationary, and accompanied by dry weather and a clear sky, which may be expected to last some time.

Prolonged absence of wind is favourable to the prevalence and spread of epidemics; but during continued windy weather no disease arising out of local causes, such as deficient water supply or inadequate drainage, is likely to make much progress.

In England windy weather is most common in December and January; then in February and November. Isolated gales of exceptional severity often occur towards the end of October and early in December. The calmest months are August and September.

The expression "an equinoctial gale" is in common use, but it will hardly bear a very

rigorous investigation, for the periods of the equinoxes are not usually marked by very definite atmospheric disturbances.

In England S.-Westerly winds predominate, taking the year as a whole. Hence it may be inferred why the W. is often the fashionable quarter of large towns, because smoke, &c. is driven from the W. towards the E. Such a current not only carries away from the W. its own smoke, but keeps away altogether smoke created in the Eastern districts of a town.

The following represents the daily prevalence of wind in England, on an average of years:—

N. ...	... 41	S.W. ...	... 104
N.E. ...	... 48	W. ...	... 38
E. ...	... 23	N.W. ...	... 24
S.E. ...	... 20	Calm ...	... 33
S. ...	... 34		

The wind is usually more strong in veering from N. to W. by S., than in veering from N. to S. by E.

Change of wind "with the Sun" (veering N., E., S., W., a matter spoken of on a previous page) is a general indication of fine weather, but "backing" (N., W., S., E.) presages wind, or rain, or both combined.

In summer a change of wind from the S. side of the compass to the N.W. is a certain forerunner of cooler weather.

A shift of the wind round to the S. or S.W. will be sure to bring mild weather, and probably rain therewith.

A dead calm often precedes a violent gale, and sometimes the calmest and clearest mornings at certain seasons are followed by a blowing, showery day.

Changes of wind in Ireland, Wales, and Cornwall usually precede changes in the Midland and Eastern Counties of England by 1½ or 2 days.

If in unsettled weather the wind veers from S.W. to N.W. at sunset, an improvement in the weather may be looked for.

Whenever a wind of some force first blows from the N., the weathercock having for some days previously pointed in another direction, one or more whole days of bright, fine weather may certainly be counted upon.

"If the wind is North East three days without rain,
"Eight days will pass before South wind again."

If after three or four days in winter the wind blows from the N.W. or N., with snow or cold rain, and then backs to the S. through W., a continuance of rain may be looked for.

If after a stiff breeze there ensue a dead calm and drizzling rain, with a fall in the barometer, a gale from the S.W. may be expected.

Strong winds are more persistent and uniform than light winds; that is to say, if a strong wind is blowing at one place, a similar wind also strong will prevail over a considerable tract of country; but if the movement of the air is feeble, very different winds may perhaps be noted at places not very far apart.

A S. wind springs up oftener and blows stronger by night than by day.

In English latitudes a Northerly current becomes more Easterly the longer it lasts; and therefore a N.E. wind is a N. wind which has come from higher latitudes than a wind which reaches us as a N. wind; and similarly a S.W. wind is a S. wind which has come from lower latitudes than our S. wind.

When a calm is succeeded by a forward motion of the wind (E., S., W., N.,) it seldom backs; but if it back it will generally return to the point whence it started before performing a complete circuit.

If the wind be S. for two or three days, it may be succeeded unexpectedly by a Northerly breeze; but a Northerly wind will not be followed by a Southerly one till after the intervention of a period of E. wind.

"When ye see the South wind blow ye say there will be heat, and it cometh to pass." (*St. Luke* xii. 55.)

Speaking generally in Europe, the most serious tempests come from the South. There is nothing new in this, as witness the following Biblical quotations:—"Out of the South cometh the whirlwind." (*Job* xxxvii. 9.) Again, "As whirlwinds in the South." (*Isaiah* xxi. 1.) Again, "And shall go with whirlwinds of the South." (*Zechariah* ix. 14.)

If the wind continues for any considerable time in the S., a period of rain may certainly be expected.

Fair weather for a week with the wind Southerly may be the forerunner of a great drought if there has been much rain previously from the S.

As a main characteristic, a N. wind is *cold;* and an E. wind *dry;* a S. wind *warm, but rarely wet;* and a W. wind *generally rainy.*

The following maxim is only too well known, and its truth only too well realised by all classes of the community:—

> "When the wind is in the East
> "It is good for neither man nor beast."

This truism is supported by many Scriptural references. For instance:—"When the East wind toucheth it, it shall wither." (*Ezekiel* xvii. 10.) Again, "The East wind dried up her fruit." (*Ezekiel* xix. 12.) Again, "An East wind shall come, the wind of the Lord shall come up from the wilderness, and his spring shall become dry and his fountain shall be dried up." (*Hosea* xiii. 15.) But many centuries before these respective prophets uttered their declarations it is recorded that in Egypt, "Behold, seven thin ears and blasted with the East wind came up." (*Genesis* xli. 6.)

The coldest point of the compass in Europe is about N.E. in Winter, but N.W. in Summer. Correspondingly, the warmest point is about S.W. in Winter, but about S.E. in Summer.

Where there is nothing special happening in the air, usually the hours of sunrise and sunset are the hours in which there is least wind; 1—2 hours after noon the time when there is most wind.

If a S.S.E. wind commences to blow gently, it will freshen gradually. If the sky becomes over-

cast, the wind will rise and may shift towards the S.W.

If the wind veers, it attains its maximum intensity between W.S.W. and W.N.W., and it never remains long in N W and N.

It is a general principle to which exceptions seldom occur, that a shifting of the wind backwards is a forerunner, or, it may be, a concomitant, of atmospheric disturbances of greater or less intensity.

In spring, if the wind shifts through W. to N., we may expect the weather to clear up suddenly and night frosts to set in, even though the thermometer at a little height above the ground may not fall to 32°.

The only winds which can preserve their directions unaltered in passing over a large tract of country are due E. and due W. winds. [The directions of all others are influenced by the Earth's rotation.]

The backing of the wind when it extends beyond S. or beyond E. indicates the probable occurrence of a cyclone, serious or not as the case may be.

The following maxim is a well-tested one :—

"When the wind veers against the Sun,
"Trust it not, for back 'twill run."

Another form of this idea is :—

"Winds that change against the Sun
"Are always sure to backward run."

When the wind veers from N. to N.E. in winter, intense cold generally sets in, the duration of

which depends on the wind staying at N.E.; for if it goes round to E., a thaw, or partial thaw, may soon be expected.

In the Northern Hemisphere cyclones generally veer from E. to W. by way of N., or against the Sun's course. In the Southern Hemisphere things are reversed. This is Buys Ballot's well-known law.* Cyclones generally move in the direction W. to E., or something like it. Their effects are most violently felt in and near the centre line of their path.

The wind usually turns from N. to S., with a quiet breeze, and without rain; but returns to the N., blowing with some force, and accompanied by rain. The strongest winds occur when the weathercock turns from S. to N. by W.

When the wind turns from N.E. to E., and two days pass without rain, and does not turn S. on the third day, and no rain falls on the third day, the wind is likely to continue in E. for 8 or 9 days all fair, and then go to the S.

If the wind shifts from S. to N. through W., there will, in winter, be snow; in spring, sleet; in summer, possibly thunderstorms, but at any rate a marked depression of temperature.

Constant shifts of wind imply general uncertainness of weather in all its features.

In noticing the wind, attention should be paid to the question whether there is only one, or more than one, current overhead; in the former case, the barometer will generally be steady and the weather fair; in the latter case the barometer will be unsteady and the weather unsettled.

* See p. 31, *ante*.

Speaking generally, in the Tropics winds and currents have a Westward tendency; in middle latitudes (say 30° to 50°) winds and currents have an Eastward tendency; in high latitudes the drift of winds and currents is mainly from the Poles towards the Equator.

Shiftings through a limited extent, such as N.W. to S.W., or E.N.E. to N.N.E., are often only the return of the vane to its original position, owing to the Equatorial or Polar current, as the case may be, regaining its supremacy.

When a calm succeeds a storm the pressure is unusually low, consequently the foul air imprisoned in the mineral of coal-pits escapes more readily, accompanied by a buzzing sound, which miners regard as a prognostic of bad weather. Accordingly it is when the barometer is low that explosions of fire-damp are most common.

Storms are invariably vorticose, that is to say, travel across a region in curved paths which do not return on themselves. This is another way of stating the fact that storms are cyclones, as explained in Chapter IV. (*ante*).

The conditions and circumstances of a storm in progress depend very much upon the wind at the moment. If the wind is S.W., the storm will not last long, but will be warm; if from the N.W. it will not last long, but will be cold; if from the N.E. it will be hard. After rain has been in progress for some time, blue sky in the S.E. indicates that fair weather will soon set in.

Squalls occurring during a storm are thought to indicate that the storm has nearly run its course.

Just prior to a tempest the atmosphere is often unusually still. [Because its great rarefaction (=low barometer) enfeebles its ability to transmit sounds.]

After a gale from S.E or S.W. to N.W., a lull of a day or two may follow, with symptoms of a continuance of bad weather; then a rapid backing of the wind through W. and S. to S.E. After this, another gale may spring up which may be more violent than the former one.

If the wind howls or veers about much, rain will follow.

> "When the wind backs, and the weather-glass falls,
> "Then be on your guard against gales and squalls."

If a breeze is blowing during the afternoon, it often subsides suddenly within an hour of sunset.

Gales of wind usually subside about sunset; but if they do not they will continue far into the next day at least.

The common expression, "It seems blowing up for rain," is often well-founded, for a continuance of dry squalls not unfrequently result in the wind ceasing and rain succeeding. Shakespeare has placed this on record in saying:—

> "For raging winds blow up incessant showers:
> "And when the rage allays, the rain begins."
> —*Henry VI.*

If (towards sunset especially) the sky clears on any part of the horizon, it is not unlikely that the wind will shortly begin to blow from the quarter in which the clearance has appeared.

When the sea gets rough on a flood tide it is a sign of wind coming.

In unsettled weather, when rain seems probable, it very frequently commences on the seacoast of England at the turn of the flood-tide, that is, as soon as it is high water. [The two preceding maxims are believed to be especially true of the S. coast of England; but whether they are true of other parts of the English coast I do not know.]

Where tides run strong at the entrance of great rivers and other analogous places, the strength of the wind is often modified by the tide, blowing strong on the flood and moderate on the ebb when the direction of the wind is straight into the river, or nearly in the line of the flood tide.

CHAPTER XIX.

OPTICAL PHENOMENA IN THE SKY.

The Rainbow.

INASMUCH as a rainbow can only occur when the clouds containing or depositing the rain are opposite the Sun, it follows that a rainbow in the evening must be in the E. more or less, and in the morning in the W. more or less; and as heavy rains in England usually come from the W., a Western rainbow suggests that bad weather is approaching, an Eastern rainbow that the rain-bearing clouds are passing away.

"A rainbow in the morning
"Is the shepherd's warning;
"A rainbow at night
"Is the shepherd's delight."

A morning rainbow is considered a forerunner of wet, stormy weather. [Because at that time of day moisture ought to be diminishing, but the presence of rain shows that such is not the case; nay, more, that the moisture is really augmenting.]

An evening rainbow is a presage of fine weather. [Because the conditions under which a rainbow can then appear is the passing away of the rain cloud to the E.; in other words, a clearing up in the W., and that at a time of day when the temperature is on the decline and condensation might naturally be expected.]

A rainbow after much wet is a prelude to fine weather, especially if it breaks up all at once. A rainbow in the morning is thought to presage much fine small rain; but a rainbow at noon, heavy rain in torrents.

Two or three rainbows on the same day may accompany weather which is on the whole fine, but very much rain may be expected in a few days.

When a rainbow appears in the wind's eye, rain is sure to follow.

When a rainbow is formed in fair weather, foul will follow; but if a rainbow appear in foul weather, fair will follow.

When a rainbow is formed in a cloud which is approaching the spectator, a shower may be expected, but when in a receding cloud the rain will shortly cease.

Various writers have attempted to draw conclusions based upon the predominance of particular colours in any given rainbow, but the conclusions arrived at are very contradictory. Perhaps an excess of red and yellow indicates approaching fair weather, and an excess of green or blue a continuance of rain.

If the predominating hue is green, more rain may be expected; but if it is red the rain will be accompanied by wind.

Another authority is more precise in these details, asserting that a predominance of dark red betokens tempestuous weather; light red, wind; yellow, dryness; green, rain; blue, an impending clearing-up.

If a rainbow appears and disappears suddenly, all the colours being faint, fair weather may be expected the next day.

Coronæ and Halos.

These optical phenomena are often confounded the one with the other, and it will be well that the distinction between them should be defined. A Corona (which is very often called a Halo) is an appearance of one or more colourless, or very faintly coloured, simple rings formed around the Moon, and concentric therewith. A Corona may also be formed around the Sun, but a solar Corona of the meteorological sort can only be seen when some expedient is resorted to for subduing the strong light of the Sun. The structure of a Corona is, as has been said, simple. If there are several concentric circles, the inner

one will be small, say from 2° to 4° in diameter. The diameter of the second will be double that of the first, and of the third three times that of the first. Where colour is traceable, the prismatic blue will be nearest the centre.

A Halo is a circle, or series of circles, of prismatic colours seen around the sun or moon. Halos often exhibit a very complicated series of circles, or portions of circles, cutting one another in a very remarkable manner and with mathematical exactness, the diameters of the circles being generally very large. Contrary to what is the case with Coronæ, in Halos the red prismatic colour is next the centre.

Coronæ are very common whenever a light fleecy cloud comes between the spectator and the Sun or Moon. They are due to the interference of the rays of light which pass on each side of the intervening globules of vapour.

Halos are formed by the refraction and reflection of the rays of light by minute snow crystals in a cirrus cloud.

Coronæ are only visible when the globules of vapour composing the cloud are nearly all of equal size. The smaller the size of the globules the greater the diameter of the corona, and this diameter will, if watched, often be seen to be undergoing change. When the diameter is contracting, the water particles are uniting into larger ones, which sooner or later will be precipitated on to the Earth's surface in the form of rain. On the other hand, if the diameter of the corona is expanding, the particles are diminishing

in size, which means increasing dryness, and consequently finer weather.

Halos, which as spectacles are extremely rare, are nearly sure to be followed by rainy and unsettled weather; in fact, a halo is a recognised characteristic of the front of a cyclone. Where the constituent circles of a halo intersect, images of the Sun (or the Moon) generally appear from the light concentrated at these points. Such images of the Sun are called *Parhelia*, or "Mock-Suns"; and those of the Moon *Paraselenæ*, or "Mock-Moons." These images also exhibit the prismatic colours of the halo.

Aurora Borealis.

It is an idea of long standing that a very bright aurora is a forerunner of an approaching storm. Assuming the aurora to be a phenomenon of electrical origin, this statement may well be true; but it must be admitted that we are not at present justified in saying confidently that it is true.

During the continuance of an auroral display, ozone abounds.

Auroras are more frequent and more brilliant on the sea coast than at a distance from it.

In countries where the aurora is common, it is said to be always brightest when a sudden thaw succeeds severe cold weather.

In general, according to Hansteen, an aurora is usually accompanied by excessive cold. And when a cold night suddenly succeeds a mild day, an auroral display often occurs on the first two evenings.

Sunrise and Sunset.

If the clouds present at sunrise break up and work off to the W. as the Sun's elevation above the horizon increases, a fine day will follow.

A gray, dull morning is nearly sure to turn to a fine clear day.

If the Sun rises distorted in form, showers may be looked for in *summer*, but settled weather in *winter*.

When the first indications of daylight are seen above a bank of clouds, it is called a "high dawn." When the day breaks on or near the horizon, the first streaks of light being low down, it is called a "low dawn." A high dawn presages wind, a low dawn fair weather.

If the sun rises red, with blackish beams, in a haze, rain may be expected; if the Western sky is red, wind.

"If red the Sun begins his race,
"Be sure that rain will fall apace."

A grey sky in the morning betokens a fine day.

Small reddish-looking clouds, seen low on the horizon at sunrise, must not always be considered to indicate rain. After any definite interval the probability of rain will depend on the character of the clouds and their height above the horizon. If they extend no more than 10°, rain may not follow till near sunset; if they reach to 20° or 30° above the horizon, rain will follow by the early afternoon; but if they reach still higher and nearly to the zenith, rain may be expected within 3 hours.

If at sunrise rays seem to emanate from the Sun, its disc being concealed by clouds, rain is indicated, and whether the rays are few or many is some index of whether the forthcoming changes will involve a moderate rainfall or seriously tempestuous weather.

If in summer the Sun at rising is obscured by a mist which disperses about 3 hours afterwards, two or three days of hot and calm weather may be expected.

The value of a red sky at sunrise as a weather forecast depends somewhat on the season. In summer such a sky betokens only occasional violent showers, but in winter the rainfall may be expected to be steady and prolonged. In both cases wind may be looked for.

A grey or pale yellow sunset is a sign of rain; a bright yellow sunset a sign of wind.

> "Evening red and morning grey
> "Set the traveller on his way;
> "Evening grey and morning red
> "Bring down rain upon his head."

If the Sun sets behind a straight skirting of cloud, wind may certainly be expected, and from the point of setting.

If the Sun sets in a clear sky with its outline sharp and of a deep salmon colour, in summer a very fine and probably hot day will succeed, but in winter a very sharp frost.

A red or orange sunset indicates that the following day will be fine, especially if there be much dew; but it may be windy. Such a sunset is very often the first premonition of an improvement in the weather after a succession

of wet and stormy days. A few orange-coloured fragments of cloud will show themselves behind a mass of heavy grey clouds which are evidently beginning to become disintegrated.

If the Sun sets in thick clouds and the E. horizon is red, purple, or copper-coloured, rain may be expected; but if it sets in a white haze, so that its disc can scarcely be discerned, wind may be expected.

If at sunset the Eastern sky is very red, wind may be expected, and if the redness reaches to the S.E., rain also.

> " Or if Aurora tinge with glowing red
> " The clouds that float round Phœbus' rising head,
> " Farmer rejoice ! for soon refreshing rains
> " Will fill the pools and quench the thirsty plains."

A red West at sunset not extending far up the sky, and having no thick bank of black clouds, will be followed by a fine day.

When the air is hazy, so that the solar light fades gradually, the Sun itself becoming invisible some time before sunset, and the general aspect of the western sky is colourless, rain will certainly follow.

When the Sun at sunset exhibits a golden yellow and ill-defined disc, with rays extending from 4° to 6°, a strong wind and much vapour exists at a considerable elevation, and rain may be expected within 24 hours.

When after sunset the Western sky is of a whitish-yellow tint, and this tint extends high up towards the zenith, rain during the night or the next day is probable.

If the Sun sets with the sky in the background

slightly purple, the sky towards the zenith being bright blue, it is an indication of fine weather.

When the Sun appears pale or colourless, or goes down into a bank of clouds, the approach or continuance of bad weather is indicated.

If the Sun sets after a fine day behind a heavy bank of clouds, with a falling barometer, rain or snow (according to the season), either in the night or the next morning, is probable. In winter, if there has been frost, such a sunset is often followed by a thaw. Sometimes what will happen will be a rise of temperature, only without any important rainfall.

The weather maxim recorded in Scripture is as true now in Europe generally as it was true in Palestine 2000 years ago—"When it is evening, ye say, it will be fair weather: for the sky is red. And in the morning, it will be foul weather to-day: for the sky is red and lowring." (*St. Matthew* xvi. 2, 3.)

When clouds tinged on their upper edge with a pink or copper-coloured hue are situated to the Eastward at sunset, or to the Westward at sunrise, wind or rain may be expected in about 48 hours—seldom much earlier.

The Moon.

If the Moon is pale, and the cusps blunt, it is an indication of rain; but if the Moon is clear and silvery, and its outline sharp, fine weather may be expected to continue.

This idea appears in another form in the old Latin adage: *Pallida luna pluit: rubicunda flat,*

alba serenat, that is, "A pale moon indicates rain; a red moon, wind; a clear moon, fair weather."

When the phenomenon known as "the new Moon in the old Moon's arms" is seen, it is a sign of rain. [Being the equivalent of the clearness of distant hills, which clearness always betokens impending rain.]

When the Moon rises red and numerous clouds are hanging about, rain may be expected very soon. According to another view, the redness of the Moon is a special indication of wind.

When the Moon is near its "Full" (on either side), as it rises in the heavens clouds frequently break up and disperse as the night wears on. This is a thoroughly well-authenticated fact, and seems to confirm the idea that the Moon imparts a certain small amount of warmth to the Earth, as observations by Lord Rosse suggest.

With the foregoing exception it may be said with great confidence that the moon has no effect upon the weather, or, as a "poet" has well put it:—

"The Moon and the Weather
"May change together;
"But change of the Moon
"Does not change the Weather.
"If we'd no moon at all—
"And that may seem strange—
"We still should have weather
"That's subject to change."
(*Notes and Queries*, Sept. 23, 1882.)

Perhaps the following utterance, ascribed to Mr W. H. M. Christie, the Astronomer-Royal, and bearing date 1896, may satisfy some minds:—

"It seems doubtful whether the moon has or has not any influence on the weather, but it is clear that in any case it can have but very little influence, as such an influence has never been detected with certainty. The Moon's phase is always changing, and there is no warrant for the popular idea that the instants of change are new, full, and first and last quarter."

If this is not clear enough, perhaps the following extract from a letter from the Meteorological Office, London, may satisfy:—

"No one in his senses can believe in the Moon's influence on the weather. The fact that storms move over the surface of the Earth is sufficient to show that if the change of weather suits the Moon in Ireland, it must fail to suit it in England."

Be it remembered that the "changes" of the Moon are a delusion. The Moon is always changing (in a sense), not simply once in seven days, as the almanacks put it.

Moonlight nights will, during a frosty period, coincide with specially severe frosts.

The Twilight.

If after sunset the W. sky acquires a purple cast, with a haziness in the horizon, the succeeding day will be fine. But should the predominating colour be pale yellow, extending high towards the zenith, the weather will be uncertain, probably unsettled.

If the twilight is unusually protracted, though the atmosphere seems very clear, the higher regions are charged with moisture which will soon be precipitated in the form of rain.

The Stars.

If the stars are clear and twinkle greatly, in summer fine weather and in winter frost are indicated.

If the stars are dull and large and are devoid of rays (in other words, if twinkling is imperceptible), rain may be expected soon.

When the stars twinkle excessively it is an indication of wind.

If on what at first seems a clear starlight night the smaller stars become difficult to detect, it may be assumed that rain is not far off.

Excessive twinkling of the stars indicates that there is much moisture approaching, which may show itself in the form of heavy dew, rain, snow, or stormy weather, dependent on the time of year and other concomitants.

The converse of this is also often true: when the sky seems very full of stars, rain, or in winter frost, may be indicated.

CHAPTER XX.

WEATHER SIGNS DERIVED FROM THE ANIMAL KINGDOM.

"THE observations of naturalists, shepherds,* herdsmen, and others who have been brought much into contact with animals, have proved

* A great number of prognostications upon alterations of the weather, derived from the actions of animals, the appearances of clouds and vegetables, the influences of Sun

most clearly that these creatures are cognisant of approaching changes in the state of the air long before we know of their coming by other signs. To many kinds of animals, birds, and insects, the weather is of so much more importance than to us, that it would be wonderful if nature had not provided them with a more keenly prophetic instinct in this respect. The occurrence of a storm would, doubtless, be the means of depriving some of the carnivora of a meal, and it is known that utter destruction would occur to the nests of some birds if the tenants were absent during a gale of wind or a pelting shower; while to vast numbers of insects the state of the weather for the fraction of a week may determine the whole time during which they can enjoy their little lives. To enable all these creatures to prepare for coming trouble, they seem to have been fitted with what is to us an unknown sense informing them of minute changes in the atmosphere, and it has long been observed that they eat with more avidity, return to their homes, or become unusually restless before the coming of the danger of which they are forewarned." *

When animals crowd together or seek sheltered places instead of scattering themselves over their usual range, rain or unsettled weather is probably not far off.

and Moon, &c., were collected and published by the Rev. John Pointer, of Slapton, Northamptonshire, in 1738, from which extracts were made, and printed in 1744 by a Mr. Claridge, under the title of "The Shepherd of Banbury's Rules for Judging of the Weather and its Changes." —(See *Gentleman's Magazine*, vol. xviii., p. 255. 1748.)

* R. Inwards. *Weather Lore*, p. 125.

Dogs becoming restless or drowsy and stupid is a sign of rain.

If a cat sneezes it is said to be a sign of rain.

When asses hang down their ears in a forward direction, or rub themselves against walls, or bray more frequently than usual, rain may certainly be expected.

Cattle and sheep browsing on hill tops or on hill sides will descend to lower levels when rain is approaching.

All shepherds agree in saying that before a storm approaches sheep become frisky and leap about and butt at one another.

When sheep bleat much in the evening or during the night severe weather may be expected.

Pigs are restless and run about when bad weather, especially wind, is approaching.

Moles are much more active in throwing up earth before rain than at other times; and if a severe winter is likely to be approaching, they will be much more industrious in storing up worms and food generally.

When birds of long flight, such as rooks, swallows, &c., hang about home and fly backwards and forwards and low down near the Earth's surface, rain or wind may be expected.

If cocks crow late and early, clapping their wings excessively, rain may be expected.

If ducks and geese seem restless, moving backwards and forwards, continually plunging into the water and washing themselves, it is a sign of approaching wet weather.

Swans flying, especially against the wind, is a sign of rough weather.

When peacocks are noisy it is a sign of rain approaching.

Rooks flying low or staying at home, or returning home in the middle of the day, is a sign of rain. If when flying high they dart down and wheel about in circles, or sit in rows on dykes and palings, wind may be expected.

The missel thrush (called in Hampshire the "storm-cock") sings particularly loud and long before rain.

When blackbirds utter an unusually shrill note or sing much in the morning rain will follow.

If woodpeckers are very demonstrative it is a sign of rain.

Magpies flying three or four together and uttering harsh cries presage windy weather.

If owls hoot freely at night it is a sign of fair weather, especially in winter.

If robins sing cheerfully high up above the ground or on housetops, it is a sign of fine weather coming; but when they sing perched low down near the ground, however fine the weather may be, a change is impending.

If starlings and crows congregate in large numbers it is a sign of rain.

When swifts are much more numerous in the spring than swallows, a hot and dry summer may be expected.

If sparrows and finches chirp a good deal rain will follow.

When sea-birds fly out early and far to seaward, moderate winds and fair weather may be

expected. When they hang about the land or fly inland, especially several miles inland, it is a certain sign that strong winds and stormy weather are to be expected.

It is a sure sign of impending rough weather when sea-gulls come up the Thames and show themselves in the London parks.

Fishes rise more than usual and swim near the surface before rainy or stormy weather.

When dolphins and porpoises come about a ship and sport and gambol on the surface of the water stormy weather may be looked for.

The sea-anemone closes before rain and opens for fine weather.

Leeches confined in a glass bottle are very sensitive to changes of weather. During fine and calm weather they remain at the bottom. When a change is impending they move upwards, many hours, it may be, in advance. If a storm is rapidly approaching they become very restless, rising quickly. When the change occurs, and is passing over, they are quiet, and begin to descend. If the rain or wind is likely to be of long duration, they will remain a considerable time at the surface, or even come quite out of the water, crawling up the side of the bottle. If thunder and lightning are at hand, they are always exceedingly agitated and restless.

If many earth-worms appear it is a sign of rain, and this is also true of glow-worms.

When frogs croak much and toads come out of their holes and walk about with legs extended, it is a sign that rain is impending.

When frogs dive below the surface of ponds, &c., out of the way, rain is certainly impending.

"When bees to distance wing their flight,
"Days are warm and skies are bright;
"But when their flight ends near their home,
"Stormy weather is sure to come."

"If bees stay at home
"Rain will soon come,
"If they fly away
"Fine will be the day."

Wasps in great numbers indicate a continuance of warm weather, and if they build their nests in exposed places that season will also be dry.

Spiders are very sensitive to changes of weather. If they are seen crawling on the walls rain may certainly be expected, especially in winter. If they work during rain the rain will not last long.

If gnats bite more sharply than usual it is a sign of the approach of rain.

A well-known writer on various interesting subjects, Dr. Andrew Wynter, thus once summarised a few common forms of prognostication, some of which have already been alluded to, but a little repetition will do no harm:—"There are certain signs in natural objects and things which should be taken in conjunction with the reading of the instruments, if we wish to make a probable forecast of the weather. For instance, when sea-birds fly far out to sea fair weather may be expected; on the other hand, when they hang about the shore or fly landward, we may be sure that the instinct of

the birds teaches them that hard and stormy weather is at hand. Land animals also give signs that may be watched with advantage. Thus when they seek shelter, and no longer rove fearlessly about the pastures, it may be judged that rough weather is at hand. A good hearing day is an indication of rain; on the other hand, when much dew falls fine weather may be expected; fog is an anticipation of a fine day. But when the air is very clear near the horizon, when the mountain outlines are particularly sharply cut, those born among them know that storms will certainly follow." *

The following doggerel verses (variously ascribed to Dr. E. Darwin and Dr. Jenner), summarise a large number of very accurate rain predictions drawn from the world of nature, some of which have already been mentioned :—

" The hollow *winds* begin to blow,
" The *clouds* look black, the *glass* is low,
" The *soot* falls down, the *spaniels* sleep,
" And *spiders* from their cobwebs creep.
" Last night the *Sun* went pale to bed,
" The *Moon* in halos hid her head,
" The boding shepherd heaves a sigh,
" For, see! a *rainbow* spans the sky;
" The *walls* are damp, the *ditches* smell,
" Closed is the *pink-eyed pimpernel;*
" Hark how the *chairs* and *tables* crack! †
" Old Betty's *joints* are on the rack;
" Her *corns* with shooting-pains torment her
" And to her bed untimely sent her;

* *Fruit between Leaves*, vol. i., p. 165.

† This is a slip of the gifted poet's pen. Cracking indicates *contraction*, and implies a drying-up of moisture, and not its development.

" Loud quack the *ducks*, the *peacocks* cry,
" The *distant hills* are looking nigh ;
" How restless are the snorting *swine!*
" The busy *flies* disturb the kine ;
" Low o'er the grass the *swallow* wings ;
" The *cricket*, too, how sharp he sings !
" *Puss* on the hearth, with velvet paws,
" Sits wiping o'er her whiskered jaws ;
" The *smoke* from chimneys right ascends,
" Then spreading back to earth it bends ;
" The *wind* unsteady veers around,
" Or setting in the South is found.
" Through the clear stream the *fishes* rise,
" And nimbly catch th' incautious flies ;
" The *glow-worms*, num'rous, clear, and bright,
" Illumed the dewy dell last night ;
" At dusk the squalid *toad* was seen
" Hopping and crawling o'er the green ;
" The whirling *dust* the wind obeys,
" And in the rapid eddy plays ;
" The *frog* has changed his yellow vest,
" And in a russet coat is dressed ;
" The *sky* is green, the *air* is still,
" The merry *blackbird's* voice is shrill,
" The *dog*, so altered is his taste,
" Quits mutton bones on grass to feast ;
" And see yon *rooks*, how odd their flight !
" They imitate the gliding kite,
" And seem precipitate to fall,
" As if they felt the piercing ball.
" The tender *colts* on back do lie,
" Nor heed the traveller passing by.
" In fiery red the *Sun* doth rise,
" Then wades through clouds to mount the skies.
" 'Twill surely rain,—I see with sorrow
' Our jaunt must be put off to-morrow."

The following running commentary on this "poem" has been framed by Mr. G. T. Ryves, and may usefully be given here :—"Here, then, in the first place, the rising of the wind, accom-

panied by a falling barometer and threatening sky ("The hollow winds begin to blow, the clouds look black, the glass is low") indicates the approach of a cyclonic depression, which, as it passes over, almost always brings with it more or less rain. The halo round the Sun or Moon is another indication of the same thing, inasmuch as halos are formed in the high, thin cirro-stratus cloud which usually precedes the denser masses of vapour which accumulate round the centre of the depression. The pale appearance of the Sun or Moon later on shows that the cirro-stratus is thickening, and therefore that the depression is still advancing. The falling of soot in chimneys, the dampness of walls, the offensive smells proceeding from ditches, &c., are the result of the damp, close condition of the air in front of an advancing depression. And to the same cause may be attributed the rheumatic pains in the joints, the shooting of corns, &c., experienced by many persons upon the approach of rain, as well as the low flight of insects, and of birds in search of them, the creaking of the woodwork of furniture, and the restlessness of many animals, as shown by their cries or movements; while, on the other hand, the appearance of toads and glow-worms in unusual numbers, and the singing of blackbirds, are indications furnished by animals to which damp weather is welcome. The unseasonable chilliness of the air in summer ("Though June, the air is cold and still") is also, in many cases, one of the first indications of the approach of the great mass of cloud and vapour which accompanies a depression. And to the

same cause is to be ascribed the closing of the pimpernel and other flowers specially sensitive to cold or damp. And lastly, an unusual transparency of the air, technically known as 'visibility' ("The distant hills are looking nigh"), is one of the most generally accepted signs of rain, though meteorologists are not agreed as to the explanation of it. . . . It may be added that 'audibility'—that is, a state of the air in which sounds are more easily heard, or at greater distances than usual—is also regarded as an indication of rain, though in this case also the reason is uncertain."

CHAPTER XXI.

SEASONAL PREDICTIONS.

A GREAT many attempts have been made by various persons at various times to lay down some rules indicative of coming weather from previous weather in connection with the seasons or the months of the year. Many of these conclusions are merely hasty generalisations of no permanent value whatever, but there are others which should not be included in this category. Those which follow are the result of very careful research and much deliberation, but it is not pretended for one moment that they will be found invariably correct or wholly consistent with one another.

The following types of weather are well recog-

nised in Great Britain :—N.E. winds in March; cold N. winds in the middle of June; wet W. winds in September.

Cold weather often prevails about March 8, April 11, April 25, and the 2nd or 3rd week in May. Warm weather about the middle of August, the 1st week in November, and the 1st week in December. Hence it follows that when at these times the weather begins to turn warm or cold, a continuance of such weather for a few days may be expected.

Mr. R. Abercrombie has sketched out what he calls a preliminary and very incomplete list of dates recording the tendency of certain kinds of weather to recur about the same season of every year. Although the transcription of his list (in a concise shape) will involve a little repetition of some of the statements made elsewhere, this will not be altogether disadvantageous, because it will enable the reader to collate for himself statements from different sources, and to compare them for his own satisfaction, or the contrary.

January 14—20.—A great barometric surge, or fluctuation in the barometer, involving a progressive change of level without a material change of shape in the isobaric lines.

February 7—10.—A spell of cold weather associated with the Northerly type. This is the first of a series of six cold and three hot periods discovered by Buchan by noting irregular flexures in the general sweep of the annual temperature curve. He found their recurrence so regular that "during the last 50 years [183- — 188-] some of them appeared every year between the

dates specified, and none failed to make their appearance in more than 5 years.

March.—The proverbial E. winds of this month are mostly due to the Northerly type, the winds being really N.E. Equinoctial gales occasionally occur about the 21st. They are sometimes of the Easterly type, but more frequently of the Westerly.

April 11—14.—Buchan's second cold period, which he identifies with the popular saying of days being borrowed by March from April, allowing for the difference between O.S. and N.S. in reckoning the calendar.

May 9—13.—A cold spell, Buchan's third period, the most celebrated of the cold periods, as it occurs all over Europe, and has been the subject of many wild theories, but was scientifically investigated by Mädler.

June.—A cold spell in the 2nd or 3rd week is associated with the Northern type. June 29—July 4, Buchan's fourth cold period.

July 12—15.—Buchan's first warm period. The popular legend* of St. Swithin (July 15) receives an easy explanation, in Abercrombie's opinion, from the synoptic charts of the Meteorological Office. Roughly speaking, the weather at the end of July is either of considerable Westerly intensity, that is, rainy; or of a Northerly type, that is, dry. If, then, there is either a rainy or a dry spell about the 15th, similar weather may be expected to last for some time, though the traditional 40 days be mythical.

* Namely, that the weather on the day in question will, if it change, endure for several weeks.

August 2—8.—A wet period. The "Lammas floods" of Scotland. 6—11, Buchan's fifth cold period. 12—15, Buchan's second hot period.

September.—Easterly and Northerly types are rare; any equinoctial gales which occur are almost invariably of the Westerly type. About the 30th, a fine period for a few days, the "Indian summer" of N. America.

October.—About the 2nd or 3rd week a spell of the Easterly type of moderate intensity is common. 18th, a fine and quiet period about this time—"St. Luke's summer."

November 6—12.—Buchan's sixth cold period, associated with the Northerly type. The 11th is "St. Martin's summer," a widely recognised warm period. About 12—15, a great atmospheric surge.

December 3—9.—Buchan's third warm period.

Buchan's periods may be more conveniently studied if exhibited in the form of a table, thus:—

COLD PERIODS.		WARM PERIODS.	
February	7—10.	July	12—15.
April	11—14.	August	12—15.
May	9—14.	December	3—9.
June	29—34.		
August	6—11.		
November	6—12.		

Of the foregoing, it may be said that the two cold periods of May and November are particularly certain to occur, and are well-defined, but

seemingly not always exactly in the same week; more often than otherwise, however, it will be found, I think, that the cold period comes in the 3rd week of each month.

The November cold period is accompanied by an unusual prevalence of N. and N.W. winds and calms; by diminution of the invisible vapour in the atmosphere; by an increase in the rainfall, both as to its amount and its frequency; and by frequent fogs.

Lord Grimthorpe has laid it down in the emphatic manner in which he lays down the law generally, that there is some connection between cold weather and the Easter full-moon. He asserts that it is very rare for the fortnight after Easter to pass without snow falling somewhere in England.

The first fortnight in January (or the days from Jan. 6—20) usually embrace the coldest period of the year.

A warm January bodes ill for the crops of the following summer, because such a January often precedes an inclement spring. On the other hand a warm and open winter (looked at as a whole) is often followed by a hot and dry summer. An early winter (that is, much cold in October or November) means a short winter (that is, very little cold in January or February).

If after a prevalence of S.W. wind a N.E. wind should set in, it is highly probable that winds more or less Easterly will prevail for some time. If the season be winter, frost and perhaps snow may be expected; if summer, the weather will become dry, warm, and bracing, without

being sultry or oppressive, except so far that the days will be sunny; and a hot sun with a clear sky and an Easterly wind is always in some sense oppressive.

If Easterly winds have largely predominated in autumn, and South-Westerly winds have begun to prevail towards the end of November, or at the beginning of December, exceptionally mild weather with storms of wind will follow till about Christmas.

Martinmas Day (Nov. 11) is very generally associated with an epoch of mild weather lasting for several days. If this mild epoch is very definite and pronounced, the following two or three months will be more or less mild and devoid of snow. But if Martinmas is cold there will be a good deal of cold weather before Christmas, but not much afterwards. [This seems a fair summary of Martinmas weather-lore, but the sayings are not very consistent.]

If Easterly winds predominate in spring largely above the average, the following summer is likely to be characterised by S.W. winds, with much rain and moisture and little sunshine. On the other hand, if Easterly winds are nearly wanting in spring they are likely to prevail in the summer, and the summer will be characterised by clear skies and dry warm bracing weather with much sunshine of a parching character, which will be trying to persons and prejudicial to vegetation.

There is some reason to believe that whatever may be the general character of the wind (that is, whether Polar or Equatorial) during a period of

about ten days at either equinox, wind of much the same character as regards its direction will on the whole prevail during the succeeding three or four months, or even up to the next equinox.

This idea crops up in various forms; for instance, it is said in Derbyshire that if on September 19 there is a storm from the S. a mild winter may be expected. Again: a S. wind on September 21 indicates that the rest of the autumn will be warm. Again; September 20, 21, and 22 rule the weather for October, and November, and December.

If the latter end of October and the early part of November be for the most part warm and rainy, then January and February will be frosty and cold, except when the previous summer has been dry.

If there has been a prevalence of low temperature, and still more if there has been snow, in October or November, then January and February will be mild.

In general a rainy winter is followed by a dry autumn in the following year, and a dry spring by a rainy autumn.

If much rain falls between February 10 and March 10 then the remainder of the spring and the following summer are likely to be more or less wet.

The severest winters are those which begin about January 6, having been preceded by a mild December.

A turning-point in the winter season often occurs about January 18, cold weather either setting in or ceasing, more or less.

In general a spring characterised by rainy mornings will be followed by an autumn with rainy evenings, and *vice versa.*

On an average of years July, especially the second fortnight, is the rainy period of the year.

A moist and cool summer often portends a hard winter.

A hot and dry summer and autumn, especially if the heat and drought extend far into September, portend an open beginning of winter, with cold to succeed towards the latter part of winter and beginning of spring.

Clear autumn, windy winter; warm autumn, long winter; wet autumn, cold and early winter.

A moist autumn and mild winter are followed by a cold and dry spring.

If there is no snow before or during January, there will be much in March and perhaps some in April.

In many parts of England and Germany proverbial sayings are to be met with relating to Candlemas Day (Feb. 2). In substance they suggest that if the weather about the first week in February is mild and open, a continuance of severe weather may be expected later on.

A mild and damp March is a bad omen for the summer crops; better that March should be cold and dry, and April cold and wet.

"A wet May—
"A big load of hay."

Where there has been no particular storm about the time of the spring equinox, if a storm arise from the E. on or before that day, or if a

storm from any point of the compass arise near a week after the equinox, then in either of these cases, the succeeding summer will four times in five be dry; but if a storm arise from the S.W. or W.S.W. on or just before the spring equinox, then the following summer will five times in six be wet.

There are generally some warm days at the end of March or beginning of April, which bring the blackthorn into bloom, and which are followed by a cold period, to which the term "blackthorn winter" has been applied.

> "A leaky May and a warm June
> "Bring on the harvest very soon."

A cold and wet June spoils the rest of the year. In Cornwall a wet June makes a dry September.

When July, August, and September are unusually hot, the following January will be cold.

If the first week in August is unusually warm, the coming winter may be expected to be long and snowy.

Much rain in October, much wind in December.

Frost and snow in October will be followed by a mild January.

A warm and green Christmas is a forerunner of a cold and white Easter.

Christmas Day and the 11 days which follow are said to give a clue to the weather of the whole of the following year. [But this seems expecting too much.]

It has recently been suggested that severe winters recur at intervals of 41 and 80 years.

But if any given severe winter is followed by another after 41 years, then the winter of the 80th year will not be severe. This statement made quite recently by a competent meteorologist is perhaps an independent revival of a statement made by the great Lord Bacon that it was in his days an old opinion that the weather repeats its changes after 40 years.

When the rainfall at Greenwich during the first seven months of the year has been large (say 14 inches or more), the mean temperature the following winter (December—February inclusive) will be in excess of, or about the average, unless the mean of the intervening period (August-October inclusive) has been remarkably cold, in which case the latter part of the succeeding winter (say February) will develope some marked extremes of cold.

In the year 1736 a Norfolk Squire, Mr. Robert Marsham of Stratton Strawless Hall, near Norwich, commenced a series of observations on the budding of sundry trees and flowers and the manners and customs of sundry birds and animals, with the view of seeing how the dates which he would thus arrive at would furnish eventually "Indications of Spring."* His observations (1736—1788) were communicated to the Royal Society in 1789. Mr. Marsham died in 1797 at the age of 90, continuing his labours almost to the last. His son Robert carried on

* This was the term which Mr. Marsham ultimately used. Perhaps it is not quite strictly historic to impute to him the motives suggested in the text as his original programme.

INDICATIONS OF SPRING

Observed in Norfolk between 1736 and 1874.

Indication.	Earliest	Latest.	Difference.	No of years observed	Medium. Date.
Snowdrop flowers	December 15, 1838	February 17, 1803	64 days.	94	Jan. 16
Thrush sings	Nov. 20, 1856, 65	March 5, 1795	105 ,,	93	Jan 11
Hawthorn leafs	January 27, 1804	April 22, 1784	85 ,,	101	March 10
Hawthorn flowers	April 13, 1750	June 2, 1799	50 ,,	97	May 8
Frogs and Toads croak ...	February 20, 1750	April 26, 1849	65 ,,	97	March 24
Sycamore leafs	February 22, 1750	May 4, 1771	71 ,,	92	March 29
Birch leafs	February 21, 1750	May 4, 1771	72 ,,	91	March 29
Elm leafs	Feb. 8, 1839, '52	May 6, 1784	87 ,,	83	March 23
Mountain Ash leafs	March 11, 1846	May 2, 1771	52 ,,	82	April 6
Oak leafs	March 31, 1750, '79	May 20, 1799	50 ,,	93	April 25
Beech leafs	April 5, 1779	May 10, 1771	35 ,,	94	April 22
Horse-Chestnut leafs	March 3, 1849	May 2, 1771	60 ,,	89	April 2
Chestnut leafs	March 28, 1794	May 18, 1855	51 ,,	73	April 22
Hornbeam leafs	February 8, 1852	May 7, 1771	88 ,,	78	March 24
Ash leafs	April 2, 1779	May 26, 1772	54 ,,	78	April 29
Ringdove coos	December 25, 1857	April 15, 1857	111 ,,	78	Feb. 18
Rooks build	January 7, 1836	March 14, 1755	66 ,,	96	Feb. 9
Young Rooks seen	March 23, 1846	April 24, 1853	32 ,,	93	April 8
Swallows appear	March 30, 1736	April 28, 1847, '72	29 ,,	103	April 13
Cuckoo sings	April 9, 1752	May 7, 1767, '99	28 ,,	106	April 23
Nightingale sings	April 7, 1752	May 19, 1792	42 ,,	93	April 28
Churn-owl sings	April 27, 1869	July 9, 1853	73 ,,	55	June 2
Yellow Butterfly appears ...	January 14, 1790	April 29, 1862	105 ,,	75	March 7
Turnip in flower	December 26, 1846	May 14, 1784	139 ,,	85	March 5
Lime leafs	March 19, 1794	May 11, 1853	53 ,,	83	April 14
Maple leafs	March 15, 1794	May 7, 1770, '71	53 ,,	53	April 10
Wood Anemone flowers ...	March 9, 1775	April 30, 1837	52 ,,	70	April 4

the work till 1810, dying in 1812. The observations of these 13 years were, with the first series, reduced to a summary form by the first Lord Suffield, and in that form were published by him on a broadside sheet now very rare and scarce. Between 1810 and 1836 no records seem to have been kept at the family mansion, but in the last-named year the work was resumed by a third Robert Marsham, who continued it till 1854, and died in 1855. After 1854 a representative in the fourth generation, the Rev. W. P. Marsham, took up the thread and kept the observations going nearly until his death in 1892. After 1855 the observations were made at another house in Norfolk, Rippon Hall, two miles north of Stratton Strawless, and now occupied by Major H. S. Marsham, a descendant in the fifth generation of the original Man of Science of *temp.* George II. Major Marsham still works on the same lines, though 1874 is the latest date to which the whole series has been summarised.

The aggregate results up to that date are given in the Table on the opposite page, drawn up by Mr. T. Southwell, F.Z.S.

CHAPTER XXII.

MISCELLANEOUS WEATHER FACTS AND SIGNS.

Domestic and Personal.

THE points which might be noted under this head would occupy a very large amount of space

if they were dealt with at all exhaustively, but it must suffice for our present purpose to make a selection of some of the most noteworthy and best authenticated.

After a continuance of fine weather, the first signs of a coming change are usually light streaks, curls, whisps, or mottled patches of white and distant clouds, which gradually consolidate into a general overcasting of the sky. Usually the higher and more distant such clouds seem to be, the more gradual but general the coming change of weather will prove.

When in winter or spring, during rough, sleety, or rainy weather, fires seem to crackle and to draw better, and to throw out more heat, the weather will probably soon clear up, and frost or frosty air follow.

When distant sounds, such as bells and railway whistles, are unusually distinct or shrill, rain may soon be expected. But this rule does not apply where the sources of the sound are situate a mile or two to the E. of the listener. In such cases, with the normal Southerly or Westerly wind of England, such sounds will not usually be very clearly heard, and their becoming such only indicates that the relatively moist S. or W. current has been replaced by a relatively dry current from the E.

Doors and windows which fit accurately in the summer or in dry weather are often very hard to shut in winter or in damp weather, and this is an indication that an abnormal amount of moisture is present in the atmosphere.

Similarly, if matting on the floor shrinks, it is

a sign of dry weather, whilst if it expands wet weather may be coming on.

Window blind cords and ropes, and cords generally, become very tight on the approach of damp or rain, so much so that if previously fairly tight they will often snap. It is under such circumstances as these that violin strings often break.

It is on the principle unfolded in the previous paragraph that the familiar toys constructed of two figures hanging under cover in a little house; the figure of the woman emerges for fine (that is, dry weather), whilst the man, significantly clothed in a great coat, comes out for bad (that is, damp weather).

If persons who are rheumatic complain of more than ordinary pains in their joints, and if corns or wounds, new or old, itch or ache more than usual, it is, especially as regards corns, a certain proof that rain is impending.

Sometimes walls will appear to be more than usually damp before the advent of rain. And the same remark often applies to paving-stones, and other large stones.

Various mineral substances are very sensitive to the presence of an increased amount of moisture in the atmosphere. This is especially true of salt.

Saline impregnations, including such things as black currant lozenges, are apt to imbibe moisture freely, and so become available as hygroscopes and indicators of rainy weather. When they deliquesce, it is because their surfaces are colder than the air which surrounds them, and therefore

they condense the aqueous vapour stored up in that air.

The fall of soot down a chimney is not simply a sign that it needs sweeping, but is very generally a forerunner of the approach of rain.

Ditches, drains, and accumulations of manure, or other decaying matter, often smell much more offensively before rain.

Forests, Trees, and Flowers.

It is a well-established fact that forests and trees increase the rainfall of a district and diminish evaporation from the soil; in other words, tend to make the days cooler and the nights warmer. [This is partly because changes of temperature take place slowly amongst trees, but rapidly in an open expanse of air; and also because trees obstruct nocturnal radiation; and when the locality is a hill-side or a slope with trees at the top they obstruct the descent of currents of cold air.]

If when the leaves ought to fall in October many wither on the boughs and seem disposed to remain there, it betokens a frosty winter with much snow.

Good harvests depend (*meteorologically*) on a warm and sunny July and August. The prevalence of too much sunny weather in June ripens the crops prematurely, whilst the absence of rain causes the grain to be deficient in size.

Crops of wheat are best after hot dry summers; beans after cool moist summers; oats and barley after summers of intermediate character.

When trees are heard in the autumn to snap and crack, it is a proof that the air is deficient in moisture, and is therefore in some degree an indication of fine weather.

Before rain the leaves of the lime, sycamore, plane, and poplar trees show a good deal more than usual of their under surfaces when trembling in the wind. [This is because the air, being damp, softens the leaf stalks and puts a tensile strain on them.]

"If on the trees the leaves still hold,
"The coming winter will be cold."

[Great differences may be noticed in different years in the fall of the leaves. Sometimes they will fall by slow degrees spread over several weeks; at other times, as in 1895, they will stay on late and come down almost all at once. Probably there is some significance in these differences in the behaviour of leaves.]

" If the oak's before the ash,
" Then you'll only get a splash ;
" But if the ash precedes the oak,
" Then you may expect a soak."

[This proverb is widespread in England, but its value is questioned by many persons.]

A piece of kelp or sea-weed hung up and dried will become damp previous to rain.

If toad-stools spring up in the night in dry weather, it is a sign that the air is becoming moist, and so, possibly, that rain is approaching.

The pimpernel is sometimes called "the Shepherd's Dial," owing to the fact that it opens and closes at regular hours. If a rustic finds the

pimpernel closed when it should be open, though the weather is at the moment fine and dry, he will yet say "there will soon be rain."

Pimpernels and marigolds close their petals, and poplars and maples show the underpart of their leaves when the air is damp. The leaves of the trees named curl under the circumstances.

"An artificial leaf of paper may be made to do the same thing if constructed on the same principle as the natural one—a hard, thin paper to represent the upper side of the leaf, and a thicker, unsized paper for the lower side—these will, if stuck together, curl up or bend down in sympathy with the hygroscopic condition of the air."

Mountains and Hills.

Mountains and hills deprive of their moisture winds which cross them, and thus tend to cause cold winters and hot summers in places to their leeward as compared with places to their windward [by more fully exposing them to both solar and terrestrial radiation].

When the outlines of distant hills are very clearly seen, and are sharply defined, and the hills themselves are dark and seemingly near, rain is certainly imminent. [The state of things is that dry winds, probably with a good deal of N. and E. in them, are suddenly followed by a moist wind, the vapour of which, condensing on particles of dust floating about in the air, makes them heavy, and therefore they sink to the ground, leaving the superincumbent atmosphere clear because dustless.]

Soils.

The surfaces of loamy and clayey soils do not heat as do the surfaces of sandy soils, because the former, being better conductors, the heat does not accumulate on the surface, but is propagated downwards. For the like reason the surfaces of rocks are cooler than the above-mentioned soils.

Arid regions are commonly deficient in vegetation, and by consequence are deficient in rainfall. [This is in some sense arguing in a circle, for it is often true that because a place is deficient in rainfall, therefore it is arid.]

The Sea.

The sea and large and deep lakes moderate the winter temperatures of the adjacent land, and especially the nocturnal winter temperatures. [Owing to the high specific heat of water, its temperature falls more slowly than that of the land; and when radiation cools the surface layers of water, they sink to the bottom, and are replaced by other layers which are of higher temperature. A constant change is therefore going on, with the result that water which is relatively warm always constitutes the top layer and the superjacent air is comparatively little chilled on calm nights.]

Ozone.

Ozone is a queer-looking word to represent a very queer thing—a peculiar odour associated with the development of electricity in the

atmosphere. Ozone itself has been commonly regarded as oxygen gas, which, under electrical influence, has undergone some peculiar change. The writer, whoever he was, who penned the words, "The problem remains in fact one of the most perplexing as well as interesting questions imperfectly resolved in chemistry," was a shrewd and "safe" man. So far as our present purpose is concerned we need only speak of ozone as a mysterious something frequently met with in the Earth's atmosphere. Its action on test papers—papers steeped in iodide of potassium—marks it out as an agent of considerable influence apparently for good, that is as a purifier, or at any rate as beneficial to health. Certain it is that its action is more strongly manifested in the air of the open country than in that of towns, and its absence would seem to imply a viciated condition of the atmosphere.

When ozone is largely present in the air it is accompanied by diminished pressure, increasing temperature and humidity, and a prevalence of S.W. or Equatorial winds. But when it is present only to a limited extent the pressure is increasing, the temperature and humidity are decreasing, and the prevailing wind is N.E. or Polar in character.

Ozone is more abundant on the sea coast than inland; in the West of Great Britain than in the East; in elevated than in low situations; in rural districts than in towns; and on the windward than on the leeward side of towns. Its amount seems to increase and decrease with the electricity in the atmosphere; and it is almost

wanting in places where there is much decaying vegetable or animal matter.

Ozone is most abundant in May, and least so in November.

All the foregoing facts point to the conclusion that ozone, if it were more widely studied and if systematic and prolonged observations of it were recorded, would become an extremely valuable and important index to the claims of a locality as a place of residence on the score of salubrity.

Spots on the Sun.

The question as to whether spots on the sun affect in any degree terrestrial temperatures and weather has often been discussed, but very little progress has been made towards arriving at an undoubted conclusion. Sir Norman Lockyer, however, has recently stated that after an examination of the records of sun-spots and the records of earthquakes during 7 years, he thinks there is reason to believe that earthquakes are most numerous and volcanoes most active at the periods when sun-spots are at their maximum or minimum. This opens up the question whether specially violent changes of weather, either hot or cold, or atmospheric disturbances generally, take place at sun-spot maxima and minima; and an examination of weather records since 1859 seems to confirm to some extent such a supposition. Thus, the years 1859-60 represent an epoch of spot maximum. The year 1859 had one of the warmest summers on record, whilst 1860 was one

of the coldest and most sunless years of the 19th century. The frost at Christmas 1860 was a very memorable one. Proceeding onwards, 1865-66 was an epoch of minimum, and 1865 had a very fine summer followed by an exceptionally tempestuous winter. 1867, the year after the spot minimum, was cold and wet until the autumn. The next maximum year was 1872, and this was the wettest year of the century. 1878-79 was an epoch of minimum. 1878 had a warm summer followed by a wet and cold winter, whilst the summer and autumn of 1879 was also very inclement. The next maximum fell in 1884-85; 1884 had a very warm summer, whilst the next succeeding summer of 1885 was cold. Passing over the minimum of 1890-91 which had no remarkable features, we come to the maximum of 1895, the early months of which were marked by a very memorable frost. The warm summer of 1901 followed by the cold summer of 1902, embrace the next minimum, which was a prolonged one.

The foregoing details, which it will be noticed are based upon half-periods more or less of the recognised sun-spot period of 11·1 years, seem sufficiently pronounced to justify the surmise that at or near every sun-spot maximum or minimum the Earth's atmosphere, in Western Europe at any rate, is marked by unusual manifestations of weather uncertainties. This conclusion, whatever its ultimate importance, is so far a new idea, because hitherto meteorologists giving any attention to the subject have generally concentrated their thoughts on a search for 11-year

weather periods rather than 5—6-year periods, assuming that because sun-spots present themselves in cycles of about 11 years, therefore weather features and atmospheric disturbances might be expected to go through an 11-year cycle.

However, as was said at the beginning of this section, though the question of sun-spots and the weather has often been raised it cannot yet be stated with any confidence, that we possess sufficient *data* on which to found clear and distinct conclusions; and many years will probably have to elapse before physicists are in a position to dogmatise on the subject.

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